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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. LVIII.—*On Subdivisions in Archæan History;* by James D. Dana.

1. *Subdivisions based on Kinds of Rocks.*

Werner's idea that kinds of rocks and grade of crystallization afford a basis for the chronological subdivision of crystalline rocks is more or less apparent in nearly all attempts that have since been made to lay down the general subdivisions of Archæan terranes. The "fundamental gneiss" has gone to the bottom and the thinner schists to the top. There is a degree of truth in the idea. But the assumptions are so great that at the present time little reason exists for the earnestness sometimes shown by advocates of such systems. The idea has little to sustain it in the known facts of geology. The following are sufficient to decide the question.

According to the thorough petrological and geological study of the rocks of the Bernardston region by Prof. B. K. Emerson*—a region in the Connecticut valley, in the towns chiefly of Bernardston, Massachusetts, and Vernon, Vermont—there are the following rocks: granite, largely feldspathic; dioryte, so like intrusive dioryte that it had been pronounced trap; quartz-dioryte; granitoid gneiss faintly foliated with biotite and passing into the granite; hornblende schist; quartzyte; quartzyte porphyritic with feldspar crystals; staurolitic and garnetiferous mica schist; hydromica schist; argillyte; massive magnetite, making a bed of magnetite rock;

*A description of the "Bernardston Series" of Metamorphic Upper Devonian Rocks, by Ben K. Emerson, this Journal, III, xl, 263, 1890.

along with coarsely crystalline limestone and quartzytic limestone containing Crinoids, Corals and Brachiopods: all together making one series of rocks of later Devonian age. My own observations in the region confirm the conclusions of Prof. Emerson. Such facts prove, moreover, that "massive" as applied to crystalline rocks does not signify *igneous*. The granite is not eruptive granite, but part of a stratum which is elsewhere quartzyte, the quartzyte graduating into granite; the latter was never in fusion.

Again: on the borders of New England and New York there are schists of all gradations from massive Cambrian gneiss to Cambrian and Hudson River hydromica schist and argillyte, the age fixed by fossils. Becker reports similar facts from the Cretaceous of California. Such observations, and others on record, make it hazardous to pronounce any gneiss in an Archæan area "fundamental gneiss," or any associated slaty schist the younger of the two. It may be true; but it may not be. It is probable that the thin-bedded schists are absent from the older Archæan, but not that the thick-bedded and massive are absent from the later Archæan.

The little chronological value of kinds of crystalline rocks in the later Archæan comes out to view still more strongly if we consider with some detail the length and conditions of Archæan time.

The earth must have counted many millions of years from the first existence of a solid exterior, when the temperature was above 2500° F., to the time, when, at a temperature below 1000° F.,—probably near 500° F., supposing the atmospheric pressure to have then been that of 50 atmospheres—the condensation of the waters of the dense aërial envelope had made such progress that an ocean, moving in tides and currents, had taken its place on the surface.* There were other millions afterward along the decline in temperature to the 180° F. mark—180° F. the mean temperature of the ocean—when, according to observations on living species, the existence of plants in the waters became, as regards temperature, a possibility†; and still other millions from the 180° F. mark to that of 120° F., or nearly, when marine animal life may possibly have begun its existence. And since cooling went on at a decreasing rate toward the end, time was also long from the

* R. Mallet estimated, in view of the density of the atmosphere—over 200 atmospheres to the square inch—that the first drops of water may have been condensed on the earth's surface when the temperature was that of molten iron. Phil. Mag., Jan., 1880.

† They live now in waters having a temperature of 200° F., Brewer, at Pluton Creek, California; 185°, W. H. Weed, Yellowstone Park. Moreover germs of Bacilli have germinated after having been boiled for an hour.

120° F. mark to that of a mean oceanic temperature of 90° F., or below it, when Paleozoic life found congenial conditions in the water. The mean temperature now is about 60° F.

The ocean, sooner or later after its inaugural, began the work of making permanent sediments, that is sediments that were not speedily recrystallized; and these sediments, through the millions of years that followed must have been of all kinds and of great thickness.

The conditions became still more like the present after the introduction of life with the further decline of temperature. Even before its introduction, iron oxides, iron carbonate, calcium carbonate, calcium-magnesium carbonate and calcium phosphate had probably commenced to form, for the atmosphere, although it had lost the larger portion of its water-vapor, still contained, as writers on the "primeval earth" have stated, the chief part of its carbonic acid, amounting to all that could be made from the carbon of the limestones, coal and carbonaceous products now in the world. It had also a great excess of oxygen—all that has since been shut up in the rocks by oxidations. And these most effectual of rock-destroying agents worked under a warm and dripping climate.

The amount of carbonic acid, according to published estimates, has been made equivalent in pressure to 200 atmospheres, or 3000 pounds to the square inch. 200 is probably too high, but 50 atmospheres, which is also large, is perhaps no exaggeration. Hence, the destruction of rocks by chemical methods must have been, as Dr. Hunt and other writers have urged, a great feature of the time; and long before the introduction of living species, the temperature had so far declined that the making of silicates must have given way in part to the making of deposits of carbonates and oxides.

But with the existence of life in the warm waters, through the still later millions of years, there should have been, as Weed's study of the Yellowstone Park has rendered probable, abundant calcareous secretions from the earliest plants, and, additions later, through the earliest of animal life. Great limestone formations should have resulted, and large deposits of iron carbonate, and perhaps iron oxides, over the bottom-sediments of shallow inland or sea-border flats, besides carbonaceous shales that would afford graphite by metamorphism.

In fact, long before the Archæan closed, the conditions as to rock-making were much like those that followed in the Paleozoic. Surely then, all attempts to mark off the passing time by successions in *kinds* of rocks must be futile. Some *varieties* of the various kinds of rocks are probably Archæan only; but not all those of its later millions of years. Even crystalline and uncrystalline may not be a criterion of chronological value.

The beds of the upper Archæan, under the conditions existing, may well, over some regions, be uncrystalline still, and may include carbonaceous shales that hold to this time their carbonaceous products. Such uncrystalline beds may now exist over the Continental Interior; for the great Interior has generally escaped when metamorphic work was in progress on the Continental borders.

The amount of carbonic acid is most readily estimated by first obtaining the probable amount for all post-Archæan sources, and then adding to this that which is indicated by Archæan terranes. The calculation is here given in detail that others may use it for deductions from other estimates.

For the estimation there are the following data. A cubic foot of pure limestone which is half calcite and half dolomite and has the normal specific gravity 2·75, weighs 171·4 pounds; and this, allowing for $\frac{1}{12}$th impurity, becomes 157 pounds and corresponds to 72 pounds of carbonic acid. A cubic foot is equal to an inch-square column 144 feet in height. Since 72 is half of 144, each foot of the column of such limestone contains half a pound of carbonic acid. Hence a layer of the limestone one foot thick would give to the atmosphere, on decomposition, half a pound of carbonic acid for each square inch of surface.

A foot layer of good bituminous coal containing 80 per cent of carbon, G=1·5, will give to the atmosphere by oxidation 1·9 pounds of carbonic acid per square inch of surface.

If the mean thickness of the limestone over the whole earth's surface, that of the oceans included, reckoned on a basis of $\frac{1}{12}$th impurity, is 1000 feet, the contained carbonic acid amounts according to the above to 500 pounds per square inch, or 34 atmospheres (of $14\frac{3}{4}$ pounds), and if the mean thickness of the coal is one foot, the carbonic acid it could contribute would be 1·9 pounds per square inch. Adding these amounts to the carbonic acid corresponding to the carbon in the mineral oil and gas and other carbonaceous products of the rocks and organic life, supposing it to be six times that of the coal, the total is 513·5 pounds, or 35 atmospheres. The mean thickness of Archæan calcium, magnesium and iron carbonates is not a fourth of that of post-Archæan. Estimating the carbonic acid they contain and that corresponding to the graphite of the rocks at ten atmospheres, the whole amount becomes 45 atmospheres.

To bring the amount up to the estimate for early Archæan time of 200 atmospheres of carbonic acid, the mean thickness of the limestone for Archæan and post-Archæan time should be taken at nearly 6000 feet.

Part of the limestone of post-Archæan terranes was derived from the wear and solution of Archæan limestones, iron carbonate, etc., and hence all the 35 atmospheres to the square inch were not in the atmosphere at the commencement of the Paleozoic. But if we reduce the 35 atmospheres on this account, to 25

atmospheres it is still an enormous amount beyond what ordinary life, even aquatic life, will endure. Reducing the estimated mean thickness for the limestone layer over the globe from 1000 to 500 feet would make the amount nearly one half less.*

The making of carbonates early began the work of storing carbonic acid and purifying the atmosphere; and the introduction of life increased the amount thus stored, and added to it through the carbonaceous materials from living tissues contributed to the earthy deposits. But with all the reductions that can be explained, the excess is still very large. It has been proved by experiment that an excess also of oxygen diminishes the deleterious influence of carbonic acid on plants; and that if the amount of this gas is made equal to that of the oxygen in the present atmosphere, plants will still thrive. How far this principle worked in early time cannot be known.

2. *Subdivisions based on Stratification.*

The stratification in an Archæan region affords the only safe and right basis for subdivisions. This method has been used in the separation of the Huronian from the older Archæan; and recently, with good success, by Irving and Van Hise in the study of the Penokee-Marquette region, or the Huronian belt of Wisconsin and Michigan. The intimate relation of the beds in the series has been worked out and their unconformability with the lower rocks thus ascertained, besides the stratification and constitution of the iron-ore series within the belt. This is the first step toward that complete study which should be carried on throughout all Archæan areas, however "complex." The distribution of the rocks and their apparent or real stratigraphic succession, whether massive or schistose, the positions of the planes of foliation or bedding, the unconformities in superposition, and those of mere faulting, and all structural conditions, should be thoroughly investigated. Correlation by likeness of rocks has its value within limited areas, but only after much questioning.† The work is

* A right estimate is very desirable. If made for North America, it could not be far out of the way to assume it to be a mean for like areas of the other continents as regards the limestone. But with the best possible result for the continents, the oceanic area, three times that of the continents, and out of the reach of investigation as to depths of bottom deposits, remains a large source of doubt.

† As a preliminary in the study of any such region, thousands of dips and strikes of planes of foliation or bedding should be taken (in imitation of Percival's work before 1842, mentioned in the note on page 440 of the last volume of this Journal), and all should be plotted on maps of large scale by means of symbols with affixed numbers recording the dips and strikes, for full comparison in the final elaboration. Even the Penokee-Marquette region needs further investigation with a clinometer-compass in hand.

Before commencing the study of any crystalline rocks, models of flexures should have been studied until the fact is fully appreciated that a flexure having an inclined axis—the commonest kind—ranges through 180°, or nearly, in its dips and strikes, and until the characters of the bedding in different transverse

easy in its methods, yet perplexing because in North America the uplifts and flexures of different periods have in general taken place in parallel directions, so that unconformabilities are disguised, especially when the two formations are nearly alike in grade of metamorphism. Follow along the overlying to places where its metamorphism is of low grade, and there may be success.

There is a first point of special importance to be accomplished by Archæan investigation. The Huronian of the Penokee-Marquette region is partially metamorphic. To the east, the iron ore, according to the describers, is mainly metamorphic magnetite and hematite; to the west, especially in the Penokee region, it is largely iron carbonate, or the ore in its original state. Other facts show a diminishing grade of metamorphism to the westward. In the Penokee district, the ore is underlaid by a bed of "cherty limestone," the chert of which, like the interlaminated jasper of the iron-ore bed, is regarded by Van Hise as probably of organic origin, like later chert. It has among the overlying beds carbonaceous shales containing, according to Chamberlin, 40 per cent of carbon, bearing thus evidence of very large organic carbonaceous contributions when in process of formation. The great beds of iron ore, the upward gradation eastward in metamorphism, the relations in position to the admitted Archæan adjoining it on the south, seem to prove the Huronian series to be Upper Archæan, as it has been generally regarded, but in a non-metamorphic and partially metamorphic condition. The question thence arises: Are the ore-bearing rocks of the Archæan of eastern Canada, New York, New Jersey and other parts of the Appalachian chain Huronian in a state of *high-grade* metamorphism? Are the chondroditic limestones, which in some localities, occur in and with the ore, part of the Huronian formation? Does the eastern iron-bearing series rest unconformably on inferior Archæan?

The *Algonkian* (or Agnotozoic) beds belong either to the Archæan or to the Paleozoic.

The Archæan division of geological time is of the same category with the Paleozoic, Mesozoic and Cenozoic; all are

sections of flexures are well apprehended. A good model for studying flexures may be made from a cylindrical stick of coarse-grained wood having the bark on (if of a smooth kind); it may be about four inches in diameter and 12 to 15 long. Draw a straight line through the center of one end; and from this line saw across obliquely to the edge at the opposite end. After planing smooth the sawed surface, the layers of the wood may then be colored by groups; and three colors, or two besides that of the wood, are better than more. The model of a flexure having an inclined axis is then complete. Cross-sections of the model may be cut and the colors added to the new surfaces. For models of overthrust flexures, this method is not practicable, as wood of elliptical section would be required. They may be made of paper-pulp of three colors.

grand divisions based on the progress of life, and they include together its complete range. There is no room for another grand division between Archæan and Paleozoic any more than for one between Paleozoic and Mesozoic. In contrast, the Algonkian division is not above the Cambrian in grade, it being based on series of rocks. Its true biological relations are in doubt, because fossils representing the supposed life of the period are unknown, or imperfectly so. The discovery in any rock so-called of Trilobites, Crustaceans, Mollusks, Brachiopods, or Crinoids, whatever the species, would entitle such rocks to a place in the Paleozoic, and either within the Cambrian group or below it. Walcott has already reported such fossils from the beds at the bottom of the Colorado cañon referred by him to the Algonkian, namely: besides a Stromatoporid, a small Patella-like or Discina-like shell, a fragment of a Trilobite and a small Hyolithes—forms which make the beds Paleozoic beyond question.

3. *Subdivisions based on Physical and Biological conditions.*

Although the physical and biological conditions of the early globe are not within the range of observation, there are generally admitted facts which afford a basis for a philosophical division of the time; and from it geology may derive instruction. The subdivisions to which we are led are the following:

I. The ASTRAL æon, as it has been called, or that of liquidity.

II. The AZOIC æon, or that without life.

1. The *Lithic era*, commencing with completed consolidation: the time when lateral pressure for crust-disturbance and mountain-making was initiated, and when metamorphic work began.
2. The *Oceanic era*, commencing with the ocean in its place: oceanic waves and currents and embryo rivers beginning their work about emerged and emerging lands, and the tides, the retarding of the earth's rotation.

III. The ARCHÆOZOIC æon, or that of the first life.

1. The *era of the first Plants:* the Algæ and later the aquatic Fungi (Bacteria); commencing possibly with the mean surface temperature of the ocean about 180° F.
2. The *era of the first Animal life;* the Protozoans, and forms related to the embryos of higher invertebrate species; commencing possibly with the mean surface temperature of the waters about 120° F., and ending with 90° F. or below.

The subdivisions, as is evident, mark off great steps in the progress of the developing earth, although the rocks bear no marks of them that can be distinguished.

The Huronian period covered, probably, much of Archæozoic time; and this is all in the way of correlation that can be said. It is well to note here that if the Eozoon is really animal in origin, the "Laurentian" rocks of Canada in which it occurs must be Huronian, or the later of Archæan terranes.

Respecting the Oceanic period it is observed above, "*commencing with the ocean in its place.*" It appears to be almost a physical necessity that the oceanic depression should have been made in the first forming of the solid crust, if the globe cooled to the surface from the center outward; that is, unless a liquid layer remained long afterward beneath the crust.

The depression was certainly made long before the close of Archæan time. For the enormous amount of rock-making of the Archæan over the continent implies the existence of emerged rocks within reach of the decomposing, eroding and denuding agencies of the atmosphere and atmospheric and oceanic waters. A submergence in the ocean of 50 feet is almost a complete protection against mechanical and chemical wear. Moreover North America has its Archæan lands not only in the great nucleal mass, 2,000,000 square miles in area, but also in the series of Archæan ranges parallel to the outlines of the nucleus, which extend eastward to the eastern limit of Newfoundland, and westward to the Pacific. And it has correspondingly shallow-water Cambrian deposits lying between these ranges from eastern Newfoundland and the coast-region of New Brunswick and Massachusetts, westward across the continent about most of the Archæan outcrops, to within 300 to 400 miles of the Pacific Ocean, as shown by Walcott.

There is hence reason for the conclusion that, at the close of Archæan time, the continent of North America was present not merely in outline, but also in general features, and at shallow depths where not emerged.

This fact with reference to North America means much. It means that by the end of Archæan time, the continents generally were essentially in a like condition—outlined and at shallow depths where not emerged; that, therefore, the oceanic depression was then large and deep enough to hold the ocean. Further, this last fact indicates, if the mean level of the continents was coincident with the water's surface, that the oceanic depression had already a depth of 12,000 feet, or that of the present mean depth of the waters; and that, the lowering, through later time, of the bed 1500 feet on an average (or 2000 feet according to other estimates) would give the continents their present mean height. And it is a fact of deep geogenic significance, that nearly 1000 feet of this mean height was received after the beginning of the Tertiary.

[To be continued.]

Fig. 1

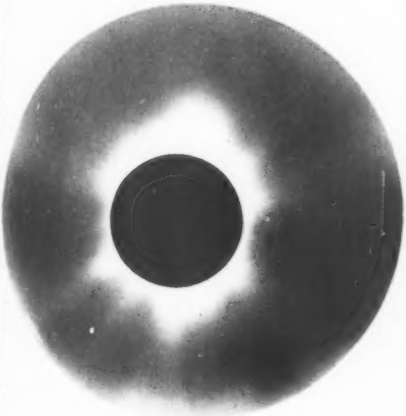


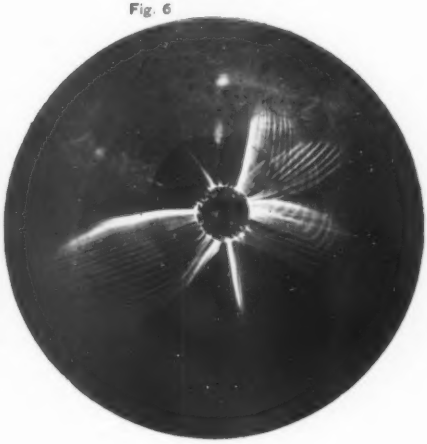
Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6



CORONOIDAL ELECTRICAL DISCHARGES (PUPIN.)

ART. LIX.—*On Electrical Discharges through poor Vacua, and on Coronoidal Discharges;** by M. I. PUPIN, PH D., Columbia College. With Plate XIV.

INTRODUCTION.

THE behavior of electrical discharges through poor vacua does not seem to have received the attention of experimental investigators which it deserves. This may seem strange in view of the uncertainty of our knowledge of the process by which the transfer of electricity through gases takes place. Considering, however, that it was generally customary to employ in experimental investigations of this kind a vacuum jar with metal electrodes in connection with an electric generator of small capacity, it is easily explained why the discharges through poor vacua should have received so much less attention than the discharges through high vacua and the spark discharges through gases at ordinary pressures. Neither the vacuum jar, nor the working of the electric generators ordinarily employed, admitted of rapid, easily adjustable, but essential variations in the conditions of the experiment; as for instance, variations of the size and shape of the electrode, of the frequency of the discharges, of the strength of the electromotive force, etc. But, as I shall point out in the course of this paper, it is through these very variations that certain fundamental features in the character of an electrical discharge through poor vacua are brought out prominently.

The fact that electrical discharges in poor vacua resemble in many characteristic details the appearance and behavior of the solar corona attaches additional interest and importance to that class of experimental investigations which are pointed out, only, in this paper. Neither time nor facilities permitted me to aim at anything approaching completeness. The principal aim in my presenting this paper was to recommend my subject and my method of investigating it to those who command over a larger experience and skill in experimental investigations, and who also have more leisure and greater experimental facilities than I could even pretend to possess.

DESCRIPTION OF THE EXPERIMENTAL METHOD.

A brief description of the method by which I obtained my vacuum discharges seems in place now. It consists in producing an electrical current in a vacuum by means of the con-

* Read before the National Academy of Sciences, Washington, April 22nd, 1892.

denser effect of tinfoil coatings or other conductors placed on the outside of a vacuum jar.

The following experiment which I performed over a year ago will explain my meaning more fully. The poles *f g* (fig. 7,) of a small Ritchie induction coil were connected to two glass

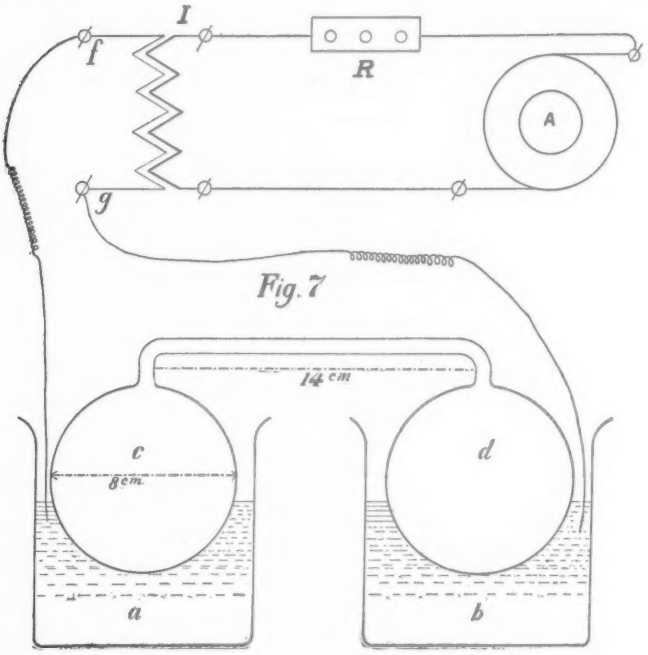


Fig. 7

beakers *a b* containing water. The primary was fed by a $\frac{1}{4}$ h. p. alternator A, giving an alternating current of about 80 periods. A resistance box R, regulates the strength of the primary current. The speed of the motor which drives the alternator regulated the periodicity of the current.

A vacuum jar *c d*, consisting of two glass bulbs (each about 8^{cm} in diameter) connected by a tube of narrow bore, was immersed into the beakers, one bulb in one beaker the other into the other. The jar contained rarefied air at about 5^{mm} pressure.

As soon as the bulb reached a certain depth a discharge took place producing a perfectly steady and continuously diffused crimson luminosity. The intensity of the luminosity increased with the increase of the surface of contact between the water and the bulbs. The same effect was produced by substituting

a Holtz machine for the induction coil and the alternator. In this case the effect was due, of course, to the oscillations produced by the spark discharge between the poles of the machine. The two vacuum bulbs with the water surrounding them act like two condensers connected in series by the narrow tube. It seems superfluous to describe the obvious experiments which I had to perform to prove the following relation:

The intensity of the luminosity increases with the condenser surface of the bulbs, with the frequency of alternations, and with the effective electromotive force of the charging apparatus. Other things being equal the total amount of light produced will increase with the increase of the conductivity of the vacuum. This relation may have been understood before, but to my knowledge it was never clearly stated.

The luminous effects which I succeeded in producing in the manner described were so powerful, that I thought it worth while to construct an electrical lamp on this principle. I mention this for the purpose of pointing out that this method of producing very powerful vacuum discharges was worked out by me several months before the publication of Nikola Tesla's and Professor J. J. Thomson's magnificent experiments. A considerable number of results which I obtained in my experiments are simply repetitions, on a small scale, of the results obtained by these scientists. There is, however, one line along which there seems to be but very few points of contact between their work and mine. This line runs in the direction of investigating the relation between the character of the discharge, the pressure in the vacuum, and the effective e. m. f. which produces the discharge. The following experiments will show some of the characteristic features of this relation.

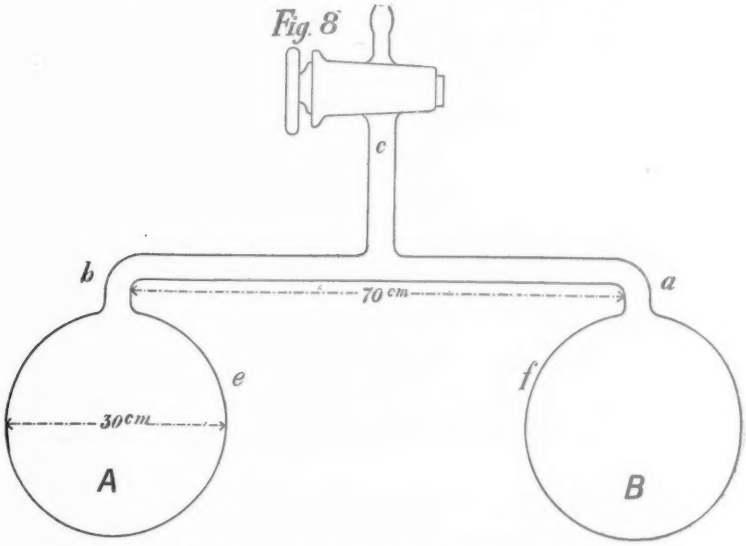
I. ON THE CRITICAL POINTS OF THE DISCHARGE.

A vacuum jar of the form and dimensions as given in fig. 8, was substituted for the small double bulb *c d*, in fig. 7. The bulbs A and B were totally immersed in large glass beakers containing clear, distilled, acidulated water. The air pressure in the bulbs was a little less than 2^{mm}. Instead of the small alternator a large alternating current machine fed the primary. On closing the primary circuit the discharge between the bulbs started long before the resistance box R, indicated that the e. m. f. in the secondary coil had reached its maximum. The crimson luminosity was very soft, steady, and distributed in accordance with the distribution of the potential which one would expect in an electrical system of the above description.

Touching the narrow tube at any point increased the luminosity below the point touched; evidently due to the increase

of the static capacity at that point. Diminishing gradually the e. m. f., the luminosity of the discharge diminished with it and then stopped suddenly as if a critical point had been suddenly reached. Reducing the e. m. f. gradually to zero

Fig. 8



and then gradually increasing it again, it was found that the discharge would cease at a point much lower than the point at which it would start again, the difference between the two points diminishing considerably with the rapidity with which these variations were made. The discharge will start at a much lower e. m. f. if solicited, that is to say if the long tube is touched at one or more points. A wire bent in the shape of a Leyden jar discharger does very good service as a discharge "solicitor."

The discharge was similarly affected by varying the capacity. Performing the last experiment, but with the small vacuum jar *c d* given in fig. 7, it was found that with a given potential (just above the critical point) the discharge did not start until the bulbs *c d* had reached a certain depth and then it started suddenly. Raising the bulbs gradually, and therefore diminishing the capacity, the discharge became fainter and fainter, but it did not cease until the bulbs were entirely lifted out of the water. On immersing again, the discharge did not start until a certain depth was reached. The depth at which the dis-

charge would start this time was smaller than in the first case and the smaller the shorter the interval between the time of taking the bulbs out and immersing them again. This difference is, of course, due to the improved conductivity of the gas and this again may in a certain measure be due to the rise in temperature of the gas on account of the heating effect of the discharge; but only in a small measure, for the bulbs were under water, so that the rise in temperature must have been very small. Besides, heating the bulbs with a Bunsen burner before immersion did not diminish the depth at which the discharge would start nearly as much as a previous discharge would, no matter of how short a duration. As stated above, the discharge may be started far below the critical point by touching the connecting tube. But if the touch lasts only a very short time (a fraction of a second) the discharge ceases as soon as the touching conductor leaves the tube. In this manner the vacuum tube may be made to blaze up in quick successions.

This behavior of the discharge at all pressures, but very much more striking at pressures higher than the pressure under consideration, seems to support the dissociation theory of Prof. J. J. Thomson (Phil. Mag. 1891, vol. xxxii, pp. 329, 454, 455).

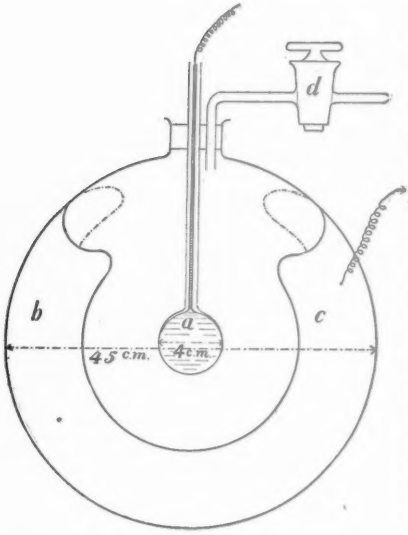
II. PHENOMENA INDICATING A DISSOCIATION OF THE MOLECULES.

The following phenomenon appears to be an additional support of this theory:

A close inspection of the discharge going on in the bulbs A and B, fig. 8, seemed to reveal the strange fact that the electrical flow was confined to a thin layer of the rarified gas which is in immediate contact with the inside surface of the bulbs, especially when the e. m. f. was not too far above the critical point and therefore the supply of the current not too plentiful. To all appearances there was a gliding film of luminous gas in each bulb extending from the mouths of the connecting tube, spreading over the inside surfaces and ending at the bottom of the bulbs in violently agitated luminous clouds which gave the discharge a hazy appearance. When the vacuum was very good both the film and the clouds were absent. There was no suggestion of a motion on the part of the gas, and the discharge had a clear luminosity. To study this phenomenon more closely the following experiment was performed:

A glass bulb *a*, fig. 9, blown out at one end of a thick glass tube of narrow bore was filled with acidulated water and

Fig. 9



placed at the center of a large glass bottle, as indicated in the figure.

A wide strip (*c b*) of tinfoil was placed on the outside of the bottle, covering about one-third of the surface. The air was exhausted through the tube *d*, until the pressure was about 3^{mm}. The liquid in the bulb *a* and the tinfoil were connected to the secondary poles of the induction coil. When the e. m. f. was not too far above the critical point the discharge was in form of numerous, quivering streamers, which looked like the generators of a conical surface with the center of bulb *a* as vertex and the edge of the tinfoil as directing curve. There was no visible discharge between the bulb and the central parts of the tinfoil. But the discharge spread out and gradually approached these parts and at the same time the streamers became less numerous and steadier, giving the discharge a more diffused appearance as the potential gradually increased. When the e. m. f. was gradually brought back to its original value the discharge diminished in intensity but did not return to its original form of distribution. It did that when the e. m. f. was considerably lowered below its initial value, which showed that the original distribution was not altogether due to the fact that at any moment the density of the electrostatic charge of the tinfoils was considerably larger near the edges. In this experiment as well as in the preceding one the number of streamers, their definition, their quivering motion, and their preference for the paths along which the discharge started, increased with the increase of pressure in the vacuum. A discharge (especially in vacua of poor conductivity) will always start between parts of highest electrical density and each successive discharge prefers the passage along the path of the first discharge on account of the increased conductivity along this path.

But if this increase in the conductivity is due to a rise in the temperature of the gas along the path of the first discharge and to nothing else, how can the fact be explained that a long, thin, discharge streamer when forced through a poor vacuum can be maintained steady, and permanent in form, even if the discharge continues for several minutes? It should broaden out continually and become more and more diffused as the adjacent particles of the air get heated. In my experiments on solitary discharge streamers in poor vacua (see this Journal, April, 1892), I did not observe any appreciable widening out, but I did observe a phosphorescent halo around the streamer which, as Prof. J. J. Thomson assumes, (l. c.) was *very probably* due to dissociated oxygen molecules that were ejected from the path of the discharge. (See further below the effect of a blast on a discharge streamer).

Still another experiment which shows that something of the nature of a dissociation of the gas molecules is going on along the path of the discharge. A thick German silver wire, 60^{cm} long, was bent zig-zag fashion into 12 zig-zag parts and placed in horizontal position at the bottom of a bottle like the one in fig. 9. A wire passing through a rubber stopper in the neck of the bottle connected this zig-zag electrode to one of the poles of the induction coil. The other electrode, a small brass sphere, was vertically above the zig-zag electrode, immediately under the rubber stopper. The shortest distance between the two was about 30^{cm}. The vacuum was about 3^{mm}. The discharge started between *the nearest points of the electrodes*, that is between the lowest point of the sphere and one extremity of the zig-zag electrode. It had the form of a band about 3^{cm} wide, intensely luminous at each end, but only very faintly luminous along the intervening three-fourths of its length. The length of the less luminous interval increased with the decrease of the e. m. f., but diminished with the increase of the gas pressure; it also seemed to have a different color, but I did not care to examine this point more closely. The phenomenon that interested me more was the gradual creeping of the discharge along the zig-zag electrode from one of its extremities towards the other. It did not increase in breadth but left its trail along the zig-zag electrode in form of a faintly luminous halo which surrounded this electrode just like a narrow luminous tube. Both the color and the gradual lateral motion of the discharge reminded me very much of the aurora borealis of Feb. 13th, 1892. (In this connection it is well to remark that when the e. m. f. is below the critical point this auroral discharge can be started by powerful disruptive discharges of a Leyden jar in its vicinity. This in connection with observations on coronoidal discharges given in the

latter part of this paper may perhaps furnish a clue in tracing the connection between sunspots and auroral discharges).

III. PHENOMENA INDICATING A TRANSLATIONAL MOTION OF THE GAS.

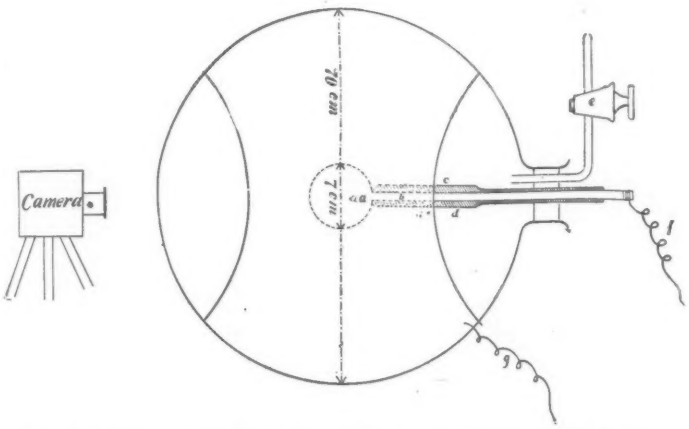
An interesting phenomenon was observed in the experiments with bulbs A, B, fig. 8, when the vacuum was diminished by turning a stop-cock C several times around. The vacuum pressure was about 20^{mm}. The induction coil had to be strained considerably to force a discharge through the long glass tube. The discharge looked like a luminous jet shooting from the tube into the bulbs, and in its path around the corners it seemed to strike against the necks of the bulbs at *a* and *b* from which points it was reflected and glided along the surface towards the points *e* and *f*. Inside of the bulbs the jet oscillated rapidly; it was also split up in several parts, each part consisting of numerous more or less intense streamers. A slight modification in the curvature of the necks modified the general outline of the luminous jet without changing its general character. With the increase of the gas pressure the phosphorescence appeared and seemed to be strongest at *a* and *b*. It was very strong in the tube C, leading to the stop-cock, although this tube was entirely free from the discharge proper. The height to which the phosphorescence rose in this tube increased with the current. Every slight variation in the current strength caused a simultaneous variation in the height of the phosphorescent column in C. (When the discharge ceased there was a strong phosphorescent after-glow all along the long tube). A similar behavior on the part of the phosphorescent gas, which I observed in the experiment described in this Journal, April, 1892, leads to the conclusion that the phosphorescent gas must have a translational motion due to its being ejected from the path of the discharge proper. This strengthened my belief in a translational motion of the gas along the path of the discharge proper, which belief was due to the phenomena in the experiment just described. It was also strengthened by the phenomenon observed in the experiment described by me in the paper cited above, the phenomenon namely that a discharge streamer made to curve out (by the repulsive action of another parallel streamer) so as to strike against the walls of the vacuum jar will rebound from this wall just as a curved jet of water would if it struck against a rigid surface. In another experiment with an apparatus similar to that described in the above paper a thin rectangular sheet of mica was suspended between and parallel to two discharge streamers and it was found that it prevented their action which I described in that paper, but

it was made to swing back and forth as if acted upon by a wind coming from the path of the discharges. This action was hardly perceptible in high vacua but increased quite considerably with the increase of the gas pressure. It may, however, be due to a great variety of causes, like peculiar distribution of pressures due to a peculiar distribution temperature; so-called apparent (in my case continually varying) electrostatic charge over the surface of the mica, etc.

IV. ON CORONOIDAL DISCHARGES.

Wishing to perform additional experiments which could throw some more light on this particular feature of the discharge, I constructed the apparatus given in fig. 10. A large

Fig. 10



glass bulb was coated with tin foil along those parts of its external surface which would approximately correspond to its temperate zones, its neck being one of the poles. This tinfoil coating had a wire *g* attached to it by means of which it could be connected to the pole of the induction coil, and serve as an electrode of the bulb. The other electrode was a brass sphere *a* attached to a brass rod *b*. This brass rod was surrounded by a glass tube *c d* and the space between the two was filled with sealing wax. In this arrangement the pressure could be varied between very wide limits (up to about 100^{mm}) without running the risk of refusal on the part of the induction coil to force a

discharge through. A camera was placed in front of the bulb as indicated in fig. 10, and the discharges photographed. Figs. 1, 2, 3, 4, 5, 6, (in the plate facing p. 462) are photographs of the discharges obtained in this manner but in various degrees of rarification.

I shall discuss the discharge given in fig. 6 first. In this case the vacuum was very poor (about 60^{mm} pressure). The discharge started in the form of four large streamers together with a very large number of short luminous jets, which were more or less uniformly distributed over the sphere. In consequence of these jets the appearance of the sphere reminded one very much of the granular structure of the sun's disc as revealed by Rutherfurd's, Janssen's, and Vogel's photographs of the sun. Very luminous spots appeared from time to time at several points of the surface, which reminded one very much of the sun's faculæ. Both the jets and the large streamers rotated rapidly. This rotation is indicated very plainly in the photograph; for the number of streamers in each wing represents the number of maxima in the alternating discharge during the time of the exposure, which was a small fraction of a second. The thickest streamers indicate the place where the discharge started. It is evident that the streamers were distributed nearly symmetrically over the sphere at the start of the discharge and that then one-half of them were gradually and almost uniformly displaced in the direction of motion of the hands of a watch, the other held in the opposite direction. The peculiar curvature of some of these streamers indicates the presence of two kinds of motion, one a translational along the prolongation of the radii of the small sphere and the other a rotational. It was this rotational motion which led me to assume that there must be some sort of repulsive action between the streamers of a vacuum discharge. The existence of this action was demonstrated conclusively by the experiment described in the paper cited above. Additional researches in this direction lead me to the conclusion that two discharge streamers tend to blow each other out owing to the motion of the cooler gas between them, this motion being produced by the enormous heating effect of the discharge. The result is that the particles of the gas which at any moment form the path of a discharge are continually displaced (particularly in a discharge through a poor vacuum), and since every successive discharge prefers the particles through which the preceding discharge passed (for reasons given above) it follows that a sort of rotary motion is set up in the various parts of the discharge.

An additional evidence in favor of a translational motion along the paths of the streamers is furnished by the fact that

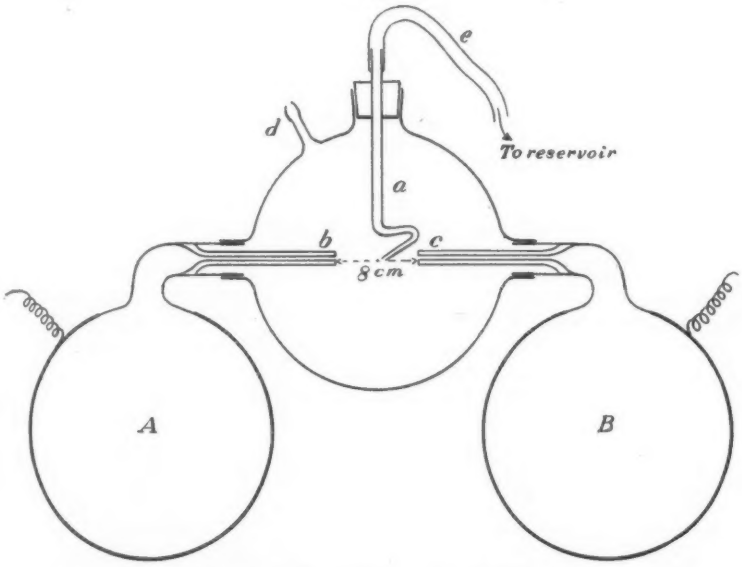
all along the inside surface of the large glass bulb, which is below the tinfoil coating, there is a hazy luminosity which increases with the increase of the discharge, and which to all appearances is due to an accumulation of incandescent gas molecules which had impinged against and were reflected by the surface of the bulb.

If the inside end of the exhaust tube *e*, fig. 10, is lowered, so that it reaches the region of the discharge it is observed that from time to time the incandescent gas shoots through this tube toward the stop-cock way out of the bulb.

EFFECT OF A BLAST ON A DISCHARGE STREAMERS.

Granting that there is a translational motion along the path of the streamer it follows that a rectilinear streamer may be transformed into a curved one by imparting to the gas in each part of its path a component velocity perpendicular to its original velocity. This inference was confirmed by the following experiment:

Fig 11



Two bulbs A B (fig. 11) coated with tinfoil on the outside (the electrodes of the system) communicated with a reservoir (which I call the principal reservoir) by means of glass tubes

b c of narrow bore. An L-shaped tube *a* with a small orifice was fitted by means of a rubber stopper into the neck of the reservoir. By means of this tube and the tube *d* of the principal reservoir communicated with two other reservoirs, which I call the external reservoirs.

The external reservoir connected with *d* communicated with a mercury pump. When the exhaustion had reached the point at which a steady rectilinear discharge could be forced from *b* to *c*, a stopcock connecting *d* to its external reservoir was shut off and the exhaustion continued until a good vacuum was obtained in the external reservoir *d*. The discharge was then started. It was a perfectly steady, narrow, rectilinear column of crimson luminosity, surrounded by a phosphorescent ellipsoidal column. But as soon as the above mentioned stopcock was turned on, the blast coming from the orifice *a* played up the column and the rectilinear path became curved at the point where the blast was acting. The discharge acted as if it bent around to get out of the way of the blast. The observation that the effect of the blast upon the phosphorescent column was incomparably stronger than upon the crimson column needs no comment. The weaker the discharge the stronger is the effect of the blast, and *vice versa* The effect of a blast upon the oscillatory spark discharge of a powerful Leyden jar battery is not perceptible.

In discharges through very poor vacua the heating effect is very unequally distributed throughout the vacuum jar. The temperature at certain points is enormously higher than at others. The result is that a very violent motion of the gas is set up, which motion may sometimes, on account of the effects pointed out in the last experiment, produce streamers of double curvature.

During an experiment with the apparatus given in fig. 10, which I performed on February 8th, 1892, before the astronomical section of the New York Academy of Sciences, a leak occurred so that the vacuum was exceedingly poor by the time I was ready to start the discharge. Finding that the discharge gave no sign of starting, I risked turning the whole power of the 10 h. p. alternator on the induction coil. Long sparks shot immediately from almost every point of the edge of the tinfoil. The discharge between the brass sphere and the tinfoil looked like a black-faced Medusa with fiery serpents dancing all around her head. On repeating this experiment I found that in very poor vacua the discharge streamers very often assume the form of spirals of very long pitch.

All these phenomena suggested to my mind a very strong similarity between the streamers of an electrical discharge

through poor vacua and those of the solar corona, and for the purpose of pointing out this similarity to others otherwise than by verbal description, only, I resolved to photograph these discharges under conditions similar to those under which the solar corona is observed. Photographs 1, 2, 3, 4, 5, 6 are the result.

The discharges were obtained with the apparatus given in fig. 10. The only additions were that a circular tinfoil disc was pasted on the outside of the large bulb, in the line of sight between the camera and the brass sphere *a*. The diameter of this disc was about equal to that of the brass sphere. Also, the inside surface of the large bulb which formed the background of the brass sphere was blackened by means of camphor smoke to avoid reflections. The discharge in fig. 1 is that of a good vacuum (about 2^{mm}), the succeeding ones represent discharges in poorer vacua, the pressures varying between 2^{mm} and 60^{mm}.

The bearing which these experimental results may have upon the theory of the solar corona I prefer to leave to others to decide. That they may prove a suggestive guide in the study of solar phenomena seems not unreasonable to expect.

I am greatly indebted to Professor John K. Rees for the interest which he took in my work, and to Mr. Mann of the Columbia College Observatory, for the very valuable service which he rendered me in photographing the coronoidal discharges.

Department of Electrical Engineering, Columbia College,
March 31st, 1892.

ART. LX.—*On the Rubidium and Potassium Trihalides;* by H. L. WELLS and H. L. WHEELER. *With their Crystallography;* by S. L. PENFIELD.

THE discovery of a series of cæsium trihalides* has led the writers to investigate the analogous rubidium and potassium compounds. The following table gives a list of the bodies which we have been able to prepare, together with the cæsium series for comparison. The compound $KI.I_2$ had been previously prepared by Johnson.†

* On a Series of Cæsium Trihalides, by H. L. Wells; including their Crystallography, by S. L. Penfield. This Journal, III, xliii, 17.

† J. Chem. Soc., 1877, 249.

$CsI . I_2$	$RbI . I_2$	$KI . I_2$
$CsBr . I_2$	------	--- --
$CsBr . BrI$	$RbBr . BrI$	$KBr . BrI$
$CsCl . BrI$	$RbCl . BrI$	------
$CsCl . ClI$	$RbCl . ClI$	$KCl . ClI$
$CsBr . Br_2$	$RbBr . Br_2$	------
$CsCl . Br_2$	$RbCl . Br_2$	------
$CsCl . ClBr$	$RbCl . ClBr$	------

It is to be noticed that there is but one member lacking in the rubidium series to make it as complete as that of cæsium. We have repeatedly tried to prepare this compound, $RbBr . I_2$, using alcoholic solutions of varying strength and great concentration at low temperatures, but with no success. The failure to make this body doubtless depends upon the comparative instability of the rubidium series. We have even attempted to prepare $RbCl . I_2$ and $RbCl . Cl_2$, corresponding to which no cæsium compounds could be made, but, as was anticipated, these efforts were entirely without success.

In the potassium series only those bodies could be prepared which correspond to the more stable cæsium and rubidium compounds. They show a great decrease in stability in comparison with the rubidium compounds. A product was obtained at a very low temperature, which was probably $KBr . Br_2$, but we did not make a satisfactory analysis of it.

We have attempted to prepare a number of sodium and lithium trihalides. There is no doubt that some of them exist, but they are so extremely soluble and unstable that we have abandoned work in this direction.

Method of Preparation.— The rubidium and potassium compounds are made, like the cæsium series, by dissolving a normal halide with the proper halogen or halogens in water with the aid of heat and cooling to crystallization. The members of the rubidium series, being very soluble, require very concentrated solutions for their preparation. The potassium compounds, being still more soluble, require the greatest possible degree of concentration and are usually best obtained by exposing the solutions for a considerable time to a winter temperature, evaporation in the desiccator being sometimes also necessary.

Color.—The colors of the rubidium and potassium compounds are very similar to those of the corresponding members of the cæsium series, but since they usually form larger crystals their apparent color is generally somewhat darker. They vary in color from brilliant black in $RbI . I_2$ and $KI . I_2$, through various shades of yellowish-red and orange to bright yellow in the compound RbCl . ClBr. In all the compounds

that have been prepared the color becomes lighter as the sum of the atomic weights of the three halogen atoms decreases.

Stability.—It has been found by experiment that the potassium trihalides are much less stable on exposure to the air than the corresponding rubidium compounds, while these in turn are less stable than the members of the cæsium series. The same relative stability of the three series is shown by the temperatures at which they are completely decomposed by rapid heating as given below:

Approximate temperature of whitening.

$CsI.I_2$ 330°	$RbI.I_2$ 270°	$KI.I_2$ 225°
$CsBr.BrI$ 320°	$RbBr.BrI$ 265°	$KBr.BrI$ 180°
$CsCl.ClI$ 290°	$RbCl.ClI$ 265°	$KCl.ClI$ 215°
$CsCl.BrI$ 290°	$RbCl.BrI$ 200°	.....
$CsBr.Br_2$ 160°	$RbBr.Br_2$ 140°	.....
$CsCl.ClBr$ 150°	$RbCl.ClBr$ 110°	.....
$CsCl.Br_2$ 150°	$RbCl.Br_2$ 80°	.....

Fusibility.—The melting-points of the analogous compounds become lower from cæsium to potassium. In the open capillary tube $RbI.I_2$ melts at 194° and $RbCl.ClI$ at 208°, while all the other rubidium compounds whiten without melting. The potassium compounds give practically the same melting-points in open as in sealed tubes. The following table gives the approximate melting-points in sealed tubes:

$CsI.I_2$ 201°–208°	$RbI.I_2$ 190°	$KI.I_2$ 38°*
$CsBr.BrI$ 243°–248°	$RbBr.BrI$ 225°	$KBr.BrI$ 60°
$CsCl.ClI$ 225°–230°	$RbCl.ClI$ 180°–200°	$KCl.ClI$ 60°
$CsCl.BrI$ 225°–235°	$RbCl.BrI$ 205°	.....
$CsBr.Br_2$ 180°	$RbBr.Br_2$ whitens	.....
$CsCl.ClBr$ 205°	$RbCl.ClBr$ whitens	.....
$CsCl.Br_2$ 191°	$RbCl.Br_2$ 76° ?	.....

Behavior with Solvents.—The extreme solubility of the rubidium and potassium trihalides in water has already been referred to, and it has been pointed out that the members of the potassium series are the most soluble. The rubidium compounds which contain iodine can be recrystallized from water without difficulty. These four bodies containing rubidium and iodine are sufficiently stable to be soluble in alcohol, while the remaining rubidium compounds, as well as all the potassium compounds, are more or less readily decomposed by alcohol with the separation of normal halides. Ether decomposes all the rubidium and potassium compounds, leaving normal halides undissolved.

* Johnson gives 45° for the melting-point of this compound (l. c.)

Crystallography.

The rubidium trihalides crystallize in the orthorhombic system and are isomorphous with the corresponding cæsium compounds, showing a close similarity both in crystalline habit and in axial ratios.

The forms which have been observed are

a, 100, i-$\bar{i}$	*d*, 011, 1-$\breve{\imath}$
b, 010, i-$\breve{\imath}$	*f*, 021, 2-$\breve{\imath}$
c, 001, *O*	*e*, 102, $\frac{1}{2}$-$\bar{i}$
m, 110, *I*	*p*, 111, 1.

With the exception of the pyramid *p*, which was observed as a small face only on $RbI.I_2$, these are the same as were observed on the cæsium trihalides, while the brachydome *g*, 012,$\frac{1}{2}$-$\breve{\imath}$ which was found only on $CsI.I_2$, was not observed on any of the rubidium compounds.

Of the three potassium trihalides, which were examined, only one, KBr.BrI, was orthorhombic, like the cæsium and rubidium compounds. The others, $KI.I_2$ and KCl.ClI, are monoclinic, but they can be referred to axes which are similar to those of the orthorhombic series.

The cleavage of the rubidium trihalides is perfect parallel to *c*, less perfect parallel to *a*; neither is easily produced. The crystals are very brittle and usually break with a conchoidal fracture. The potassium trihalides are exceedingly brittle and no cleavage was observed. The optical properties were not studied, owing to the difficulty of preparing orientated sections.

In the following table the axial ratios of all of the alkali-metal trihalides are given, arranged as in the cæsium paper. In the table of angles, those which were chosen as fundamental are marked by an asterisk.

	I. Series with iodine.	II.
	a : *b* : *c*	*a* : *b* : *c*
$CsI.I_2$	0·6824 : 1 : 1·1051	1 : 1·4655 : 1·6196
$RbI.I_2$	0·6858 : 1 : 1·1234	1 : 1·4582 : 1·6381
$KI.I_2$	0·7065 : 1 : ----	1 : 1·4154
	Monoclinic, $\alpha = 86° 47\frac{1}{2}'$	$\alpha = 86° 47\frac{1}{2}'$
$CsBr.I_2$	0·6916 : 1 : 1·1419	1 : 1·4460 : 1·6511
CsBr.BrI	0·7203 : 1 : 1·1667	1 : 1·3882 : 1·6196
RbBr.BrI	0·7130 : 1 : 1·1640	1 : 1·4025 : 1·6325
KBr.BrI	0·7158 : 1 : 1·1691	1 : 1·3970 : 1·6333
CsCl.BrI	0·7230 : 1 : 1·1760	1 : 1·3831 : 1·6268
RbCl.BrI	0·7271 : 1 : 1·1745	1 : 1·3753 : 1·6153
CsCl.ClI	0·7373 : 1 : 1·1920	1 : 1·3563 : 1·6167
RbCl.ClI	0·7341 : 1 : 1·1963	1 : 1·3622 : 1·6296
KCl.ClI	0·7335 : 1 : 1·2204	1 : 1·3633 : 1·6638
	Monoclinic, $\alpha = 83° 20'$	$\alpha = 83° 20'$

Series without iodine.

{ $CsBr.Br_2$	0·6873 : 1 : 1·0581	1 : 1·4550 : 1·5395
{ $RbBr.Br_2$	0·6952 : 1 : 1·1139	1 : 1·4384 : 1·6023
{ $CsCl.Br_2$	0·699 : 1 :	1 : 1·430 : ....
{ $RbCl.Br_2$	0·70 : 1 : 1·1269	1 : 1·43 : 1·61
{ CsCl · ClBr	0·7186 : 1 : 1·1237	1 : 1·3917 : 1·5638
{ RbCl . ClBr	0·7146 : 1 : 1·1430	1 : 1·3994 : 1·5995

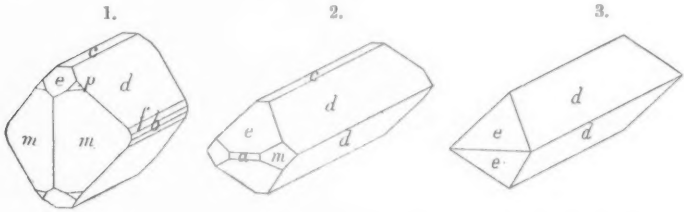
	$m \wedge m$, $110 \wedge 1\bar{1}0$	$d \wedge d$, $011 \wedge 0\bar{1}1$	$e \wedge e$, $102 \wedge \bar{1}02$
$RbI.I_2$	*68° 53′	*96° 39′	78° 38′
$KI.I_2$	*70 34		
RbBr . BrI	70 58	*98 40	*78 27
KBr . BrI	71 12	*98 55	78 28
RbCl . BrI	72 2	*99 10½	*77 51
RbCl . ClI	72 34	*100 13	*78 21
KCl . ClI	72 54		*79 8
$RbBr.Br_2$	*69 37	*96 10	77 24
$RbCl.Br_2$	*70 approx.	*96 58	76 approx.
RbCl . ClBr	71 6	*97 38	*77 18

A comparison of the axial ratios of the trihalides shows that the replacement of cæsium by rubidium, and in one case by potassium, has little or no effect on the form, while in two of the compounds potassium causes a change in symmetry without much change in the axes. It is evident that the rubidium salts like those of cæsium may be arranged in two symmetrical series, one with and the other without iodine, in which the ratio of two axes remains nearly constant throughout while the third varies, and the conclusions which were arrived at in our previous paper concerning the constitution of the cæsium trihalides, are confirmed by the rubidium compounds.

The rubidium trihalides have a strong tendency to crystallize and the solubility is such that, from solutions of not over 50 c.c. in volume, large and magnificent crystals, several centimeters in length, can readily be obtained. The size of the crystals seems often dependent only upon the volume of the solution and the size of the vessel containing it. Many of the large crystals are complex, being built up of smaller ones in parallel position. Some of the crystallizations were as beautiful as any that we have ever seen.

The rubidium trihalides containing iodine were measured at ordinary temperatures; those without iodine and the potassium trihalides at about 0° C. It was found that the stability of the compounds increased very rapidly with a diminution in temperature and, by working in the cold, no difficulty was experienced in making accurate measurements of the more unstable salts. It is not considered necessary to give with each trihalide

a table of measured and calculated angles, but in all cases, where a series of accurate measurements were obtained, they agreed closely with the calculated.



RbI . I_2. The forms *b*, *c*, *m*, *d*, *f*, *e* and *p* were observed. Of these *f* and *p* were always small and frequently wanting. The habit is shown in fig. 1.

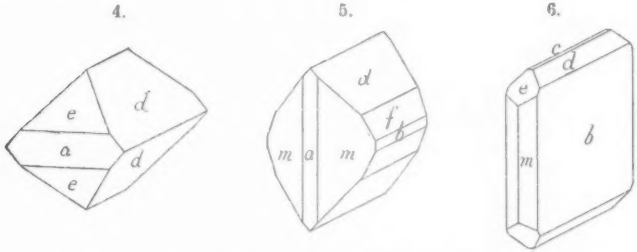
RbBr . BrI. The forms of *a*, *c*, *m*, *d* and *e* were observed. The habit is shown in fig. 2.

RbCl . BrI. The forms *a*, *d* and *e* were observed. The pinacoid *a* is usually wanting and the simple habit shown in fig. 3, prevails.

RbCl . ClI. The forms *a*, *d* and *e* were observed. The habit is shown in fig. 4.

RbBr . Br_2. The forms *a*, *b*, *m*, *d* and *f* were observed. The habit is shown in fig. 5.

RbCl . Br_2. The forms *b*, *c*, *m*, *d* and *e* were observed. The habit is shown in fig. 6. The tendency of this salt is to crystallize in small scales; it is also the most unstable of the rubidium

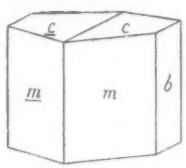


series, so that we considered it fortunate that we were able to make out the axial ratio. The only faces which yielded good reflections were $\bar{b}$ and *d*, which established accurately the relation between the $\bar{b}$ and $\dot{c}$ axes, while only approximate measurements were obtained from the other faces.

RbCl . ClBr. The forms *a*, *b*, *m*, *d* and *e* were observed. The habit is like fig. 2, except that *c* is wanting.

KI. I_2. This occurs in very simple monoclinic crystals. If the solution is cooled slowly it forms in stout prisms, but by rapid cooling a net work of fine needles is obtained. In order to make this salt and the monoclinic KCl . ClI conform to the position which has been adopted for the orthorhombic trihalides it is necessary to deviate from the ordinary custom and make the clino-axis slope from right to left instead of from back to front. The faces are taken as *b*, 010, $i\text{-}\bar{i}$; *c*, 001, *O* and *m*, 110, *I*. The crystals are not sufficiently modified to determine more than two axes, but taking as fundamental measurements, $b \wedge m$, $010 \wedge 110 = 54° 43'$ and $c \wedge c$ (reëntrant angle of twin crystal) $= 6° 25'$ the following axial ratio is obtained $a : b = \cdot 7065 : 1$; $a = 0\bar{1}0 \wedge 001 = 86° 47\frac{1}{2}'$. The angle $m \wedge c$, $110 \wedge 001$, was measured 91° 55′ and 91° 50′, calculated 91° 51′. Fig. 7 represents a twin crystal in the above position. Fig. 8 represents a simple crystal in the ordinary monoclinic position,

7.



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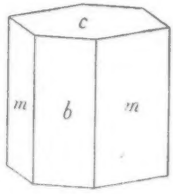

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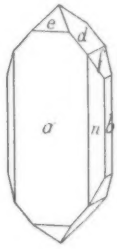
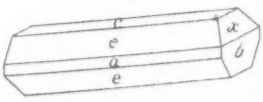


with $\dot{a}$ as the clino axis. The axial ratio for this position is, $\dot{a} : \dot{b} = 1\cdot 4154 : 1$; $\beta = 86° 47\frac{1}{2}'$.

KBr. *BrI*. The forms *a*, *b*, *n*, *d*, *f* and *e* were observed. The habit is shown in fig. 9. This salt differs from all of the other alkali-metal trihalides in having the brachy prism *n*, 120, $i\text{-}\breve{2}$, instead of the unit prism *m*. The fundamental measurements were $a \wedge n$ $100 \wedge 120 = 55° 4'$ and $d \wedge d$, $011 \wedge 0\bar{1}1$, $= 98° 55'$.

KCl. *ClI*. This crystallizes in long needles belonging to the monoclinic system, fig. 10. Taking *b* as the clino axis, the forms are *a*, 100, $i\text{-}\dot{\imath}$; *b*, 010, $i\text{-}\bar{i}$; *c*, 001, *O*; *x*, 032, $\frac{3}{2}\text{-}\bar{i}$, and *e*, 102, $\frac{1}{2}\text{-}\dot{\imath}$. The measurements taken as fundamental are $c \wedge b$, $001 \wedge 010 = 96° 40'$, $e \wedge e$, $102 \wedge \bar{1}02 = 79° 8'$, and $c \wedge x$, $001 \wedge 032 = 66° 35'$ from which the following axial ratio was calculated, $a : b : c = \cdot 7335 : 1 : 1\cdot 2204$,

10.



$a = 83° 20'$. If taken in the ordinary monoclinic position with e as the prism 110 and x as the orthodome $\bar{1}01$, the axial ratio from the above measurements becomes $\dot{a} : \bar{b} : \dot{c} = \cdot8319 : 1 : \cdot4544$ $\beta = 83° 20'$.

Method of Analysis.

The methods used for the analyses of the potassium and rubidium trihalides were exactly the same as those mentioned in the article on cæsium trihalides.

The crystals were prepared for analysis by pressing between papers and at the same time crushing them somewhat. In some cases, where the bodies were very easily decomposed, this was done in cold weather out of doors, but even with this precaution it was not possible to dry them very thoroughly or to avoid a considerable amount of decomposition.

RbI. I_2.

This body can be prepared by dissolving 55 g. of rubidium iodide in enough water to make a solution of 50 c.c., adding 60 g. of iodine, warming until solution takes place and cooling to ordinary temperature. A mass of large crystals in parallel position, forming steps, is usually formed.

	Analysis gave		Calculated for RbI . I_2.
Rubidium	18·32	18·32	18·33
Iodine	81·07	....	81·67

A specific gravity determination, made in the mother-liquor at 22° gave the number 4·03. This cannot be considered very exact on account of the difficulty of obtaining the mother-liquor in such a condition that it neither dissolves nor deposits the substance. A sample of mother-liquor, of specific gravity 2·19, was found to contain 1·61 g. of RbI . I_2 in 1 c.c. The compound therefore dissolves in about one third its weight of water at 22°. It is interesting to notice here that under nearly the same conditions, the corresponding cæsium compound, CsI . I_2, requires more than one hundred parts of water to dissolve it. It is expected that this great difference in solubility will form the basis of a useful method for separating the two metals.

RbBr . BrI.

This compound can be readily made by dissolving, with the aid of heat, 30 g. of iodine and 20 g. of bromine in a saturated aqueous solution of 40 g. of rubidium bromide and cooling. The facility with which this body crystallizes is remarkable. The large crystals have a color and luster much like the mineral pyrargyrite, "ruby-silver."

	Analysis gave	Calculated for RbBr . BrI.
Rubidium	22·79	22·95
Bromine	45·19	42·95
Iodine	31·11	34·10

An approximate specific gravity determination, made with the mother-liquor, gave the number 3·84. An analysis of the mother-liquor showed that it contained about 44 per cent of RbBr . BrI. The mother-liquor of the corresponding cæsium compound contained only 4·45 per cent of CsBr . BrI.

RbCl . BrI.

This body can be made by adding 27 g. of bromine and 42 g. of iodine to a saturated aqueous solution of 40 g. of rubidium chloride, warming until all is in solution and cooling. It forms magnificent crystals which can be readily recrystallized from water. Unlike the corresponding cæsium compound, it does not change its composition by recrystallization, hence it is probable that it is a true chemical compound and not a mixture of the isomorphous bodies RbBr . BrI and RbCl . ClI.

	Analysis gave,		
	Original crystals.	6th recrystallization.	Calculated for RbCl . BrI.
Rubidium	26·67	27·34	26·06
Chlorine	10·65	----	10·82
Bromine	24·89	----	24·39
Iodine	38·13	----	38·72

RbCl . ClI.

A convenient method for preparing this compound is to pass chlorine into a warm, concentrated solution of rubidium chloride, containing the calculated amount of iodine, until the iodine is just dissolved. If too much chlorine is used, the compound $RbCl_4I$ is formed, which we shall describe in a future article. It is best to stop adding chlorine while the solution is still colored red by iodine. On cooling the liquid the compound separates, usually in large flat groups of parallel crystals.

	Analysis gave	Calculated for RbCl . ClI.
Rubidium	29·85	30·15
Chlorine	24·68	25·04
Iodine	44·68	44·79

RbBr . Br_2.

This can be prepared by adding 49 g. of bromine to 45 c.c. of an aqueous solution containing 50 g. of rubidium bromide, warming gently until bromine dissolves, then cooling. It usually forms a mass of large, brilliant, red crystals in parallel position.

	Analysis gave	Calculated for $RbBr.Br_2$.
Rubidium	25·86	26·26
Bromine	73·09	73 73

$RbCl.Br_2$.

This body is prepared by adding bromine to a warm, saturated solution of rubidium chloride until some bromine remains undissolved and cooling to a low temperature. The compound crystallizes well, but it is the most unstable of the seven rubidium trihalides that have been prepared, and, although it was not fully dried, the sample used for analysis suffered a considerable amount of decomposition.

	Analysis gave		Calculated for $RbCl.Br_2$.
Rubidium	32·57	-----	30·42
Chlorine	14·46	14·44	12·63
Bromine	49·04	49·40	56·93

In one attempt to prepare this trihalide too much water was used and it was necessary to evaporate off the bromine and concentrate the solution. This operation was repeated several times, after fresh additions of bromine, before the proper conditions were arrived at, and the product finally obtained was contaminated with $RbBr.Br_2$, as is shown by the following analyses:

	Found.		Calculated for $RbCl.Br_2$.	Calculated for $RbBr.Br_2$.
Rubidium	28·78	----	30·42	26·26
Chlorine	7·66	6·94	12·63	0·
Bromine	60·92	61·37	56·93	73·73

We have found by experiment that rubidium chloride is partly changed to bromide by evaporating an aqueous solution of it with bromine.* This explains the formation of the $RbBr.Br_2$.

$RbCl.ClBr$.

This compound can be prepared by adding 33 g. of bromine to a saturated solution of 50 g. of rubidium chloride, passing chlorine to saturation into the slightly warmed solution, and cooling to a low temperature. The substance is usually deposited in the form of very large, light yellow prisms.

	Analysis gave		Calculated for $RbCl.ClBr$.
Rubidium	35·42	35·41	36·15
Chlorine	29·27	28·96	30·02
Bromine	31·56	31·39	33·82

* This is in accordance with the results of Potilzin referred to by Mendelejeff in his "Grundlagen der Chemie" (German ed., 1891) p. 538.

$KI.I_2$.

This body can be made in a few hours by dissolving the theoretical amount of iodine in a hot saturated aqueous solution of potassium iodide and exposing the resulting solution to a winter temperature. It can also be made as Johnson states* by evaporating the solution in a desiccator for a long time. Johnson states that he always obtained a crop of potassium iodide before the tri-iodide separated. We have never obtained such a product, undoubtedly because we have invariably used a sufficient amount of iodine.

It was not considered necessary to make a new analysis of this body.

KBr. BrI.

This compound can be prepared by making a very concentrated, warm solution of the calculated amounts of potassium bromide, bromine and iodine, and exposing it for some time to a low temperature. The product used for analysis was well crystallized, but it suffered rapid decomposition on exposure to the air.

	Analysis gave		Calculated for KBr . BrI.
Potassium	12·21	----	11·99
Bromine	51·25	51·61	49·06
Iodine	30·42	29·11	38·94

KCl. ClI.

To prepare this substance, chlorine is passed into a warm mixture of calculated quantities of potassium chloride and iodine in the presence of an amount of water insufficient to dissolve the potassium chloride even when hot. The stream of chlorine is stopped as soon as the iodine has been converted into the monochloride, for otherwise Filhol's well-known compound $KCl.Cl_2I$ will be formed. Everything is then dissolved by warming and cautiously adding water if necessary and the solution is exposed to a low winter-temperature. The crystals are very unstable, but apparently not quite as much so as KBr . BrI.

	Analysis gave		Calculated for KCl . ClI.
Potassium	15·29	15·35	16·49
Chlorine	27·53	27·50	29·94
Iodine	50·37	50·12	53·56

Other Double-halides.

The double-salt CsI . AgI was described in connection with the caesium trihalides as being isomorphous with them as far

* Loc. cit.

as the crystals could be measured. Much work has since been done, without avail, in the hope of obtaining better crystals of this compound. Unsuccessful efforts have been made to obtain measurable crystals of all the corresponding silver double halides (except the fluorides) with cæsium, rubidium and potassium. Two or three of these compounds had already been described and it is probable that we could have proven the existence of all the rest of them, but the poorly crystallized products obtained had no interest in this connection and were not analyzed. Repeated efforts also failed to produce from potassium iodide and cuprous iodide a double salt that could be measured.

Theoretical.

Arguments were given in the article on the caesium series which have led us to regard the trihalides as belonging to the class of bodies called double halides. We have indicated this view in the present article by using the usual formulæ for such compounds.

The well-known idea of a linking group of two halogen atoms as an explanation of the structure of double halides was advocated for the caesium trihalides, and, since the rubidium and potassium compounds are entirely analogous, it is unnecessary to give their structural formulæ here. We believe, however, that the trihalides throw some light upon the constitution of the diatomic linking group. Remsen says,* "I cannot see that at present we have any evidence which justifies us in the use of the expression $-Cl=Cl-$ rather than $-Cl-Cl-$." If, as we believe, the structure of rubidium tri-iodide is expressed by the formula $Rb-(II)-I$, the structure of the linking group probably cannot be $-I-I-$; for in that case a single bivalent iodine atom could do the linking as well as a group of two, and we should expect the existence of di-iodides, no evidence of which, or of any other dihalide has been found in the course of an elaborate investigation of the alkali-metal polyhalides. Moreover, with the assumption of bivalent halogen atoms, there would be no difficulty in supposing four halogens to be linked together and the existence of tetrahalides would be anticipated. Our investigations, however, have shown the existence of only tri- and pentahalides.† The double linking seems therefore the more probable of the two forms mentioned by Remsen, but it may be added that any union weaker or stronger than the others in the molecule, and

* Am. Chem. Jour., xi, 312.

† The pentahalides will be described in a future article.

different from them, would also explain the non-existence of dihalides and tetrahalides.

Assuming that there is a linking group of two halogen atoms in the trihalides, the view advanced, from a consideration of the cæsium compounds, that the most stable bodies have identical atoms in this group is confirmed by the study of the rubidium and potassium analogues. For, on this assumption, all the potassium compounds which could be made contain a group of identical atoms, while in the missing rubidium compound they are dissimilar.

Sheffield Scientific School, March, 1892.

ART. LXI.—*On the Clinton Iron Ore;* by C. H. SMYTH, JR.

RECENT articles discussing the minute structure and the mode of formation of the Clinton iron ore have suggested the publication of certain observations made upon this peculiar deposit, particularly as it appears at the type locality, Clinton, N. Y.

At this point there are three beds of ore, associated with green and gray shales and thin-bedded sandstones sometimes so coarse as to become conglomerates. The character of the sediments and their rapid changes both vertically and laterally, the presence of ripple marks and mud cracks throughout the series, and the abundant fossils, all indicate deposition in shallow water with constantly shifting conditions. The dip of the strata toward the southwest is so slight as to be hardly noticeable at the exposures.

The upper bed of ore, locally known as "red flux," varies in thickness from four to six feet, and appears to be made up of pebbles and irregular fragments of organisms coated with ferric oxide, cemented by calcite. Twenty-five feet below this is a two foot bed of workable ore, and one to two feet lower still, the third bed.

The ore in both of the lower beds is wholly made up of small round grains, usually flattened to lenticular shape, but often nearly spherical, and averaging perhaps 1^{mm} in diameter. The entire mass thus presents, aside from its color, the appearance of an oölitic limestone.

After studying numerous thin sections, from various localities, Dr. A. F. Foerste* has concluded that the oölitic appearance of the Clinton ore is due to its being made up of rounded fragments of Bryozoa in which the lime is replaced by iron.

* On the Clinton Oölitic Iron Ores; this Journal, III, xli, p. 28.

He states that "in no case, however, was anything noticed leading to the opinion that concretionary segregation of iron had taken place either around the bryozoan fragments or otherwise." Had Dr. Foerste's observations extended to the two lower beds of ore at Clinton, he would have been led to modify this statement, for in these the concretionary structure is very marked. It is unnecessary to employ the microscope to observe this. If the ore be coarsely broken and the separated spherules placed on a steel plate and tapped lightly with a small hammer, each spherule will break into a series of concentric shells, and finally a nucleus will be reached, which is nearly always a rounded fragment of quartz. In thin sections, owing to the opacity of the material, this structure may be easily overlooked, unless the section is ground extremely thin (a difficult matter with this ore), or is examined by reflected, as well as transmitted, light. Thin sections show well the character of the quartz around which the iron is segregated. The fragments are all well rounded, having been subjected to the attrition of the waves along a coast line. Inclusions of liquid and gas are very abundant, besides long needles of rutile and scales of micaceous hematite. The derivation of the quartz from granitoid or schistose rocks is evident.

On treating the spherules with hydrochloric acid the iron is dissolved, and there is left a perfect cast of the spherule in silica, containing a little argillaceous material. This siliceous cast or skeleton of the spherule is, of course, transparent and in it the concentric structure can be seen more perfectly than in thin sections. The number of layers is seen to be large, often ten or more. With polarized light the silica appears sometimes to be amorphous, but usually gives aggregate polarization, like that often seen in chalcedony. Thus, the two lower beds of ore at Clinton are truly oölitic, consisting of grains of sand enclosed in concentric shells of intimately associated ferric oxide and silica.

A sample of the Clinton ore from Dodge County, Wis., kindly furnished by Dr. W. H. Hobbs, gives similar results. This ore is an almost incoherent mass of spherules, associated with rocks quite different from those at Clinton, but the spherules have the same concentric structure, and give the same siliceous skeleton with hydrochloric acid. There is one marked difference, however; the quartz nucleus is greatly reduced in size in the Wisconsin oölite, or is more often entirely absent. Samples of Clinton ore from Rochester and Ontario, N. Y., Chattanooga, Tenn., Dade County, Ga., and Birmingham, Ala., have been examined, and though none of these are strictly oölitic in appearance, still, the spherules in varying proportion are scattered through them. Moreover, when the ore consists

chiefly of bryozoan fragments more or less completely replaced by iron, as described by Dr. Foerste, there is often a coating of the fragments with layers of iron associated with silica, precisely as in the oölites.

The treatment of these samples with hydrochloric acid further shows that the lime of the bryozoa has often been replaced not by iron alone, but by iron and silica, for there is left as a residue from the treatment a siliceous cast of each fragment. In most cases the iron is removed from this by the acid, but in some samples the silica prevents the complete solution of the iron, even with prolonged digestion. Apparently there is an intimate association in the deposition of iron and silica.

The above facts, together with others gathered in the field, seem to have some bearing upon the question of the origin of the Clinton ore. Most of the recent writers on this subject seem to agree that the ore is formed by the replacement of limestone strata by iron derived from the overlying rocks. The iron is taken into solution by circulating meteoric waters containing carbon dioxide and other products of organic decay. This solution coming into contact with limestone, chemical action ensues, the iron is precipitated, and the lime passes away in solution.

While there can be no doubt that many ore bodies have been formed in this way, and among them portions of the Clinton ore, still, several facts lead to the conclusion that other portions of this deposit require a different explanation. Compared with the great extent of Clinton ore, the writer's observations have been so limited as to make it, perhaps, unwise to base upon them any broad generalizations. The following discussion will, therefore, be confined almost entirely to the type locality and such other localities as have been examined in person.

As above stated, the ore at Clinton is associated with undoubted shore deposits, and though all of the rocks are calcareous, there are none that could be called limestones.

During that portion of Silurian time represented by these strata, the region was one of shoal waters or extensive mud-flats. These conditions are favorable for the formation of an iron ore by sedimentation, and it seems unnecessary to bring in the idea of replacement. If the ore represents an oölitic limestone, each spherule has been altered from the outside toward the center. This alteration has been by the replacement of the calcite by silica and iron carbonate. It would seem as though, after the exterior layers were thus altered, they must, to a greater or less extent, protect the interior layers from change, and that there would often be some trace of the original calcite. In no case has this been seen, even in the leanest ores, although

the layers of silica and iron are often so dense and impervious that hydrochloric acid cannot dissolve all of the iron present.

Further, it is difficult to account for the present chemical condition of the ore on the substitution theory. This theory postulates that the iron is taken into solution in the overlying rocks by circulating waters containing organic matter. The iron would thus be brought to the limestone in the form of carbonate and would be precipitated in that form. In highly tilted strata it is easy to see that currents of water coming more directly from the surface, along the dip, might contain oxygen instead of the products of organic decomposition and thus cause the precipitation of the iron as hydrated oxide, or convert to that form a previously precipitated carbonate, as described by Professor Van Hise in his paper on the Marquette ores.* But when, as in New York State, the strata are horizontal, such an explanation will not suffice. Yet in no case has there been seen anything to indicate that the ore was once a carbonate. If this ore was once a carbonate, what agent has so completely altered it to the peroxide?

The character of the overlying rocks presents another stumbling block in the way of replacement. Both shales and sandstones are very calcareous. It is difficult to understand why meteoric waters should dissolve iron from some calcareous strata and deposit it in others lower down. The two actions are incompatible. As a matter of fact, the waters that soak through these overlying rocks are so heavily charged with carbonate of lime that they deposit it wherever there is an opportunity, and layers of calcite are abundant on outcropping ledges and in small veins. How can such water be the bearer of iron salts that are supposed to be precipitated by lime carbonate at a lower level? There is nothing to indicate that the percolating waters have not always been thus charged with carbonate of lime.

The character and relations of the so-called "bottom tier" are of interest. If it be a substitution product, the iron must have passed through the two-foot bed of rich ore and the one to two feet of shale separating the two beds. This shale is so hard and dense that it would seem almost impervious to water. Any iron-bearing solution which may have passed through this rock must have done so very slowly and the conditions for the complete replacement of calcite were most favorable, and yet there is some five per cent of calcite still present and no indication of replacement. The "bottom tier" ore is quite lean, about thirty per cent iron, but this is due to an increased percentage of silica, rather than of lime. It is, in fact, a fer-

* C. R. Van Hise: The Iron Ores of the Marquette District of Michigan: this Journal, III, xliii, p. 116.

ruginous sandstone, differing from the richer ore in that the grains of sand which form the nuclei of the spherules are much coarser, and the deposit of iron around them correspondingly thinner. The difference in the richness of the ores is not, then, dependent chiefly upon a greater or less amount of water action, but is inherent in the two layers as deposited.

Associated with the ores are many irregular patches and layers, both calcareous and argillaceous, containing a varying proportion of spherules. Though the rock may not contain ten per cent of iron, still the spherules are just as ferruginous as in the purer ore. If they resulted from replacement, they would naturally be only partially changed. If thin sections be prepared from these specimens, it is seen that the spherules are identical with those of the ore, though completely surrounded by pure calcite. How is it possible for an iron bearing solution to pass through this compact calcite until the spherule is reached, and then begin to deposit the iron and replace the calcite? It is not uncommon to see spherules of which the outer layers have partially separated from the core, the space thus formed being filled in by the clear calcite cement.

Such occurrences as these can be explained only by the supposition that the spherules were ferruginous when incorporated into the rock. In samples of this character, iron oxide is also present in the form of flakes or scales scattered through the cement. These scales have sharply defined borders and do not pass gradually into the calcite. If the rock were igneous, the iron oxide would, without doubt, be considered an older constituent than the enclosing calcite, and there seems to be no reason for thinking that this is not equally true in the sedimentary rock. Let the proportion of oölites and scales of iron oxide be increased in these hard layers, or, let the calcareous cement be dissolved out by meteoric waters, and the result will be an ore precisely like the two oölitic beds.

The foregoing facts have led the writer to the conclusion that the oölitic ores at Clinton are not of secondary origin, but were deposited as hydrated peroxide of iron in the shoal waters of wholly, or partially enclosed basins along the coast of the Silurian sea. The intimate association of silica with the iron of the spherules seems to indicate that they were deposited together. Doubtless a greater or less amount of the iron was in suspension rather than in solution, and it seems possible that even in this condition it would take the oölitic form, being cemented in the layers of silica. Plausibility is lent to this idea by the fact that the silica is usually more or less stained by grains of argillaceous material; and occasional

masses of oölite are seen, made up wholly of such material, cemented by silica, and yet with the concentric structure just as perfect as in the iron oölite. This would seem to indicate that it is only necessary to have the silica in solution, in order to form oölites. That the silica has not been substituted for calcite by the action of circulating waters, is indicated by the fact that the spherules are inclosed in calcite showing no sign of alteration.*

The formation of oölitic iron ores under conditions somewhat similar to those of the Clinton shore is going on in many places at the present time,† and these ores have but to be dehydrated to resemble closely the Clinton ores There seems to be no doubt that dehydration takes place slowly at ordinary temperature,‡ but even if this be not so, the Clinton ores may easily have been subjected to the comparatively slight rise of temperature necessary for rapid dehydration.

Some years ago Professor H. S. Williams called the writer's attention to a thin layer of oölitic iron ore in Cuba, Allegany Co., N. Y., which is of especial interest in this connection. The ore forms a very thin bed, perhaps an inch or two in thickness, and often entirely wanting, in a series of arenaceous and argillaceous shales of Devonian age. The rocks are of shallow water origin, as stated by Professor Williams,§ and there is not the slightest evidence that the ore was ever an oölitic limestone. In fact, the character of the ore and of the associated rocks plainly indicates that the conditions under which they were formed were most unfavorable for the production of limestone of any kind. The ore was undoubtedly deposited in its present form. This ore differs from the Clinton only in the smaller size of the spherules. The quartz nucleus is not relatively so large and is sometimes absent, but there is the same perfection of concentric structure, and the same silica skeleton left by hydrochloric acid. That the two widely separated ores were formed in the same way seems certain; that they are not derived from preëxisting limestone seems, to the writer, almost equally certain.

Thus far the discussion has been limited to the oölitic ores, as these, perhaps, present the greatest difficulties in the way of accepting the replacement theory. But much that has been said of them applies with equal force to the non-oölitic varieties.

* See E. H. Barbour and J. Torrey, Jr.: Notes on Microscopic Structure of Oölite with Analyses; this Journal, III, xl, p. 246.

† J. S. Newberry: The Genesis of the Ores of Iron: School of Mines Quarterly, November, 1880.

‡ W. O. Crosby: On the Contrast in Color of the Soils of High and Low Latitudes. American Geologist, viii, p. 72.

§ H. S. Williams: On the Fossil Faunas of the Upper Devonian, the Genesee Section, New York: Bulletin 41, U. S. Geological Survey.

It seems to be generally assumed that if an ore becomes hard and calcareous below drainage level, it must be a result of replacement of a calcareous layer by iron. While this is, doubtless, often true, there are many cases where the evidence is against it. That there has been a replacement of the calcite of various organic forms by iron there is no doubt, for the ore is often largely made up of such casts. But there seems to be good reason for believing that this replacement, in many cases, occurred before the fossils were incorporated into the rocks of which they now form part, or, at least, before the rock was lithified by the calcareous cement. The replacement of bryozoa, etc., is just as complete in the hard, calcareous ores, as in the softer varieties. The completely replaced fragments are often found scattered through, and surrounded by, pure calcite. As in the case of the oölites, how is it possible that the calcite of the fossils could have been replaced by iron, after the fossils had been cemented together in this way? Even assuming the fragments to consist of aragonite, and therefore more readily attacked than the calcite cement, it would be impossible for the ferruginous solution to reach them, completely enclosed as they are in the cement. Many specimens collected not only in New York, but also in Tennessee, Georgia and Alabama illustrate these facts on both a macroscopic and microscopic scale. There seems to be no relation between the richness of the ores and the completeness of replacement of organic forms.

These points are well illustrated by the mode of occurrence of the ore at Ontario, Wayne Co., N. Y. Here there is a bed of ore some two feet thick, capped by six feet of fairly pure limestone with shale partings. All above this has been removed by erosion. The replacement theory supposes the iron to have passed through this limestone, replacing the lower two feet. It is difficult to understand why the upper portion should not cause precipitation as readily as the lower two feet, but its light gray color shows that it has not. This might possibly be explained by assuming that an impervious layer at the bottom checked the water, and thus allowed more time for the reaction. Granting this to be the case, we should expect a gradual transition from the ore to the limestone. But, as a matter of fact, the only sense in which this is true, is that some of the fragments of which the ore is composed are scattered through the lower portion of the limestone; they are just as ferruginous as in the ore below and are inclosed in pure limestone. Thus, there is a mechanical, but in no sense, a chemical transition such as would result from replacement. The contact is exactly similar to that of a limestone and fine conglomerate, the lower portion of the former including some

of the pebbles of the latter. The conclusion seems inevitable that the ore was in its present condition when the limestone was deposited upon it.

If these ores are altered limestones, it is as difficult as with the oölitic variety to account for their complete oxidation.

These facts suggest that the calcareous remains were subject to the action of waters containing iron and silica resulting in a replacement of the calcite, before the fragments were cemented into rock form. Such an action would take place only near shore, and that it was near shore that they were deposited is shown by the fragmental and rounded character of the fossils. This substitution may have taken place partly while the fragments were being rolled about on the bottom, and partly after they were massed together and covered with thin layers of mud or sand. Under these conditions ferrous carbonate formed would be quickly oxidized. Associated with this material would be a varying amount of iron oxide deposited from suspension. The coarser particles would supply the scales seen in the ore, while the finer portions might enter into the replacement, being cemented by the silica. Let such a layer as this be covered by other strata and be cemented by calcite, partly derived from a foreign source and partly from solution and crystallization of unaltered shells, bryozoa, etc., and the result would be the non-oölitic Clinton ore. When an ore formed in this way is elevated and inclined at such an angle that surface water may work down through it, there is, of course, a solution of the calcareous cement while the iron is untouched and as a result the amount of iron is relatively increased. Thus, above drainage level the ore becomes soft, porous, and rich, while below, it remains hard and calcareous. The character of an ore then depends, first, upon the amount of iron originally deposited, and secondly, upon the amount of lime removed by leaching. In many, perhaps in most, cases where the ore is said to run into limestone below drainage level, the limestone is decidedly ferruginous and is, in fact, a lean ore, requiring only the removal of its lime to make it available for working.

Samples taken at the Eureka mine, Oxmoor, Ala., illustrate well this relation. The ore at the surface is soft and porous, while a specimen taken 158 feet down the dip is hard and compact, showing cleavage faces of calcite. Subject the latter sample to the action of water containing carbon dioxide, and the result would be an ore indistinguishable from the surface piece. When the ore is in a horizontal position, as in New York and Wisconsin, and covered by a mass of rocks more or less calcareous, it would seem doubtful if there has been even this relative increase in iron. For by the time surface waters

reach the ore they must be so loaded with lime as to be able to take up little, if any, more. At Clinton, wherever the ore has been broken in any way, this abundance of lime in the waters is shown by a deposit of calcite, filling cracks and cavities.

This idea of replacement of organic forms before they were incorporated into the rocks, or, at least, before the mass of which they form part was buried under any considerable amount of sediment, raises the question, 'Was not the oölitic ore originally calcareous, the spherules being altered in the same way, before consolidation?' While there is nothing to absolutely disprove such a supposition, and further study may lead to its acceptance, it seems, on the whole, rather improbable. In the first place, the conditions seem to have been more favorable for the formation of an iron, than of a lime oölite, and so there is good reason for accepting the simpler and more direct explanation. As before stated, the absence of any traces of calcite in the spherules precludes the idea. Further, the analogy of the Cuba ore suggests direct deposition. In the truly oölitic ores seen by the writer there is a marked absence of fossils, while the non-oölitic types are full of traces of life. This indicates some decided difference in the conditions under which they were deposited. The simplest explanation seems to be, that while the non-oölitic ores formed along shore lines subject to wave and current action by means of which the organic remains were concentrated and brought within the influence of the ferruginous waters, the oölitic ores were deposited in partially or wholly enclosed basins, in which the water was too strongly charged with mineral matter to support much life. As both varieties would often be forming simultaneously quite close together, it is not strange that they show a tendency to grade into each other. The oölitic ores, then, were precipitated as such in shallow basins, while the non-oölitic varieties are a substitution product, but this substitution of iron for lime took place while the organic fragments were being rolled about in the shoal waters, or after they were loosely aggregated in a mass somewhat resembling the coquina of the Florida coast.

These suggestions as to the origin of the Clinton ore, of course, apply only where it is associated with shore deposits. But even with such conditions, it is highly improbable that the explanation will suffice for every case. On the contrary, it seems certain that, with a large amount of ferruginous material brought into sediments forming along several hundred miles of coast, iron deposits would be accumulated by various processes. Probably some beds of Clinton ore were formed by replacement, as ordinarily understood; others by original deposition as outlined above; and still others by a combination of

both processes. The objection has often been raised against the theory of original deposition that it does not account for ores associated with deep sea rocks.* But why should not the shore and deep sea deposits of ore be formed by entirely different processes? If the drainage waters of any area discharge so much iron into the sea that sediments formed at long distances from shore contain sufficient iron in twenty or thirty feet vertically to form two feet of the ore by concentration, these same drainage waters must deposit great quantities of iron both chemically and mechanically along the shore line. Thus, the accumulation of both shore and deep-sea deposits of iron would go on simultaneously, but the latter would require a secondary concentration to render them of practical value.

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ART. LXII.— *Wilde's Explication of the Secular Variation Phenomenon of Terrestrial Magnetism;* by L. A. BAUER, C. E.

[Read before the Philosophical Society of Washington, Feb. 27, 1892.]

IN 1871 Prof. Hornstein of Prague made known his discovery of a periodic change in the magnetic elements of 26⅔ days, almost exactly equal to the synodic rotation of the sun, as deduced from the equatorial sun-spots. It was then said that "this method of discovering the time of rotation of the unseen solid body of the sun by its effects on the magnetic needle was the first installment of the repayment by Magnetism of its debt to Astronomy." And true it was. For three centuries a vast amount of time and money has been spent on terrestrial magnetism. It has engaged the most brilliant minds. Money and industry have not been wanting. Zeal and enthusiasm have not been wanting. The numerous magnetic observatories already established and the vast bulk of observations already accumulated will bear ample witness. We are, however, still only on the threshold of this mighty subject and have not yet learned its very alphabet. "The field of investigation into which we are introduced by the study of terrestrial magnetism is as profound as it is extensive," says Maxwell. "What cause," inquires he, "whether exterior to the earth or in its inner depths, produces such enormous changes in the earth's magnetism, that its magnetic poles move slowly from one part of the globe to another?

*J. P. Kimball: Genesis of Iron Ores by Isomorphous and Pseudomorphous Replacement of Limestone. American Geologist, viii, p. 352.

When we consider that the intensity of the magnetization of the great globe of the earth is quite comparable with that which we produce with much difficulty in our steel magnets, these immense changes in so large a body force us to conclude that we are not yet acquainted with one of the most powerful agents in nature, the scene of whose activity lies in those inner depths of the earth, to the knowledge of which we have so few means of access." The time is at hand for another Halley, or another Gauss, to put new life into this most fascinating subject and give birth to a new and more productive terrestrial magnetism.

Hornstein's discovery has been abundantly verified since, and now we are to consider an attempt equally as bold as his, for its author believed he had reached such results that he felt able to declare himself thus confidently: "From the various movements of the declination and inclination needles, correlated with each other in time, direction and amount, on different parts of the earth's surface, the theory of a fluid interior may now be considered to be as firmly established as the doctrine of the diurnal rotation of the earth on its axis." If this be true more than one science has become the debtor to terrestrial magnetism.

The experiments upon which this bold declaration was based were announced in a paper read before the Royal Society, June 19, 1890, by Mr. Henry Wilde, F.R.S., entitled "On the Causes of the Phenomena of Terrestrial Magnetism, and on some Electro-Mechanism for exhibiting its Secular Changes in its horizontal and vertical Components." This paper having evidently been well received was followed six months later by another, embodying further investigations, "On the Unsymmetrical Distribution of Terrestrial Magnetism," and on June 11, 1891, still another was read "On the Influence of Temperature upon the Magnetization of Iron and other Substances."

These three papers have now been combined and the pamphlet printed in English, French and German. Owing to the great promise they apparently hold forth and the interesting physical questions involved, they are receiving marked attention at the hands of terrestrial magnetists. In this country a brief description was given it and the claims of the author were set forth in the January number of the American Meteorological Journal, but no attempt whether of verification or discussion made. And on February 3d, 1892, appeared an editorial in the N. Y. Tribune under the caption: "A Scientific Mystery Unravelled." To the writer's knowledge no effort as yet has been made to refute Mr. Wilde's theory. He, having in his possession the means of instituting a comparison between fact and theory and being familiar with the comprehensive investi-

gations of the Coast and Geodetic Survey undertook an examination of Mr. Wilde's paper with the result of being forced to reach a conclusion somewhat at variance with the favorable comments already noted.

Wilde's attempt may be classified as a twofold one: (1.) He seeks to account for and reproduce those great changes in the earth's magnetism taking place with the lapse of time, termed its secular variation. Thus at London, about the year 1657, the magnetic needle pointed exactly north and south. It then marched westward until about the year 1818 when it pointed 24° 38′ to the west of north. After remaining stationary for a few years, it began to turn backward on its course and march eastward, so that in 1890 it pointed but 17° 26′ to the west.

(2). He seeks to account for and reproduce the unsymmetrical distribution of terrestrial magnetism as manifested to day, by which there are at present three well-defined lines in the northern hemisphere where the needle points truly north while there are but two in the southern hemisphere.

The time allotted will only permit me to make brief mention of the second and third papers: and in regard to them it is believed that Mr. Wilde has reached most interesting and valuable results. The purpose of my paper, however, is to consider the first part, viz: the secular variation of terrestrial magnetism, and as time will not allow me to discuss all the results reached by Wilde, I will select those stations where he has actually attempted to *reproduce* the secular variation and upon which certain constants of his theory depend. These stations are: London, Cape of Good Hope, and St. Helena. I will further limit myself by discussing only the secular variation as manifested in their declinations, for only on them do the constants referred to, depend. If we succeed in overthrowing these three cases, we have overthrown Wilde's theory.

Let us see what his theory is. Perhaps we have met with the germ of it before. To avoid the danger of giving a misconception of it, I have thought it best to give his own words as far as possible.

"It is assumed that the ring of cosmical matter, from which the earth was evolved, resolved itself into a spheroid of glowing vapors, similar in constitution to those of the sun in its present condition.

From the experience we have of the cooling of bodies from a state of vapor, and by the law of continuity, the outer portions of the spheroid would, in the course of time pass from the gaseous to the liquid, and thence to the solid condition. As the specific gravity of the principal constituents of the terrestrial globe is less in the solid than in the liquid state, the

earth would then consist of a solid external crust covering a liquid shell, leaving the interior of the globe in its primitive gaseous condition.

It is not necessary for the argument to assign any particular thickness for the solid and liquid spherical shells, although there are reasons for thinking that the thickness is not very considerable, as recent investigations have shown that the elementary substances, at great depths, are of much higher specific gravity than those on which the mean density of the earth has been determined.

The remarkable relations which subsist between terrestrial magnetic disturbances and the period of sun-spot frequency, abundantly show that the solar vapors are highly electro-dynamic. It may consequently be inferred that a spherical mass of incandescent vapors of similar constitution to those in the sun, and enclosed within the solid terrestrial envelope, would also be similarly electro-dynamic.

It is also postulated that the glowing terrestrial spheroid at one period of its history revolved with its axis of rotation at right angles to the plane of its orbit, and the spheroid being symmetrically electro-dynamic, the compass needle would point due north and south on every meridian of its surface. Now, if we further assume that the polar axis of the solid and liquid globe was tilted over about its centre at a definite angle, without affecting the plane of rotation of the internal electro-dynamic sphere of vapor, and if the latter rotated with a somewhat slower motion than the solid external shell, then would all the principal phenomena of terrestrial magnetism be manifested.

It is not necessary to consider the causes which produced the present inclination of the earth's equator to the plane of its orbit, beyond suggesting that it may have been brought about by a disturbance of equilibrium through the rupture of the lunar ring on the transition of that body from the annular to the spherical form."

This is the foundation of his theory. Assuming now that the earth has passed through the following electro-dynamic and electro-magnetic stages, he attempts to reproduce them.

(1.) "The electro-dynamic condition of the terrestrial globe, at a period of its history when the crust, from its high temperature, was non-magnetic, its surface of uniform curvature, and the electro-dynamic polar foci of the internal sphere of vapors inclined at a definite angle from the poles of the earth's axis."

(2.) "The electro-dynamic and electro-magnetic condition of the earth, when its outer crust was uniform in curvature and had cooled down sufficiently to become permanently magnetic,

with dual foci of intensity coincident with the poles of the earth's axis, and separate from the dual polar foci of the internal sphere of vapors."

(3.) "The unsymmetrical distribution of the magnetic elements arising from the unequal curvature and foldings of the earth's crust during its secular cooling, as indicated by the present distribution of land and water on the terrestrial surface."

He then seeks to embody his idea in a mechanism, which he terms a Magnetarium and with it endeavors to demonstrate the correctness of his theory. A brief description of it in its final form is as follows: A plain, geographical globe, 16 inches diameter, had wound round the whole of its surface insulated copper wire, the winding beginning at the poles and ending at the equator; the terminals were then passed through the interior and brought out at the poles, where they were joined with the free ends. It was then mounted on capped axles, cemented to opposite sides of the wired surface of the globe, at an angular distance from the poles of at first 18°, but changed finally to 23·5°, the polar distance of the poles of the ecliptic. At these axles were the contrivances for establishing permanent electrical connection with the generator of electricity, when the globe was made to revolve on its axis. This represented the gaseous or electro-dynamic sphere. Then another terrestrial globe, 18 inches diameter, was cut through equatorially and the hemispheres mounted at the poles on hollow axles, made to fit over the axles of the inner globe so as to revolve separately and concentrically with it. These hemispheres, to render them permanently magnetic, were lined internally with iron wire gauze, covered with insulated copper wire wound similarly to the inner globe, and were magnetized by a branch of the current exciting the latter. These two globes were then mounted on a fixed standard in such a manner that any point up to latitude 72° could be brought directly below the contrivance bearing specially constructed magnetic needles, two inches in length. The axles were connected with an epicyclical train of wheels so that a differential motion could be imparted to the globes such that for a complete revolution of the former, the latter lost $\frac{1}{30}$ of a revolution or 12°. The relative strength of the inner and outer fields of force was adjusted by introduction of wire resistances so that the point of vertical dip would be maintained in latitude 72°, and the known maximum west declination and inclination at London would be produced. By throwing the wheels out of gear and moving the two spheres through the same angle, the magnetic elements at all points of the globe for the same epoch could be obtained. By turning the crank

and knowing the amount in time of the retardation of the inner sphere for a complete rotation of the outer, the secular variation at any point could be ground out.

It will be seen that Wilde has presented us with a totally different idea in his mechanism from that of his theory. His *theory* would have the internal sphere differentially rotating about its axis of magnetization with the plane of rotation parallel to that of the ecliptic. Nothing whatever is said as to its transportation about the terrestrial axis, as a whole. Hence, the magnetic pole would be a transient one and be induced successively on every meridian during the diurnal rotation of the terrestrial shell, and the maximum effect would appear in the diurnal variation of the needle and not in the secular. But we know that the former is but a small percentage of the latter, hence it must be evident that Wilde has not given us his whole theory. Are we to suppose that the gaseous sphere rotates about an axis which itself rotates about the terrestrial axis and is thus continually changing its plane of rotation during every twenty-four hours? Only in this way could a permanent pole be maintained.

In his *mechanism* he has the inner sphere differentially rotating about the axis of the outer with its axis of magnetization inclined to it at an angle of 23·5 degrees. This certainly simplifies the physical conditions. But are we to suppose that when the plane of rotation of the inner sphere gradually changed its primitive direction until it coincided with the outer one, the axis of magnetization of this vaporous sphere was so rigid that it remained fixed? Is it possible that Wilde wishes us to understand that the circulation of currents of electricity round the inner sphere is equivalent to a rotation of the sphere?

The first point made in this paper, then, is that Wilde's mechanism does not coincide with his theory as he has given it to us.

But now let us set aside all discussion as to the theory and the physical conditions involved and discuss the results from the standpoint of Terrestrial Magnetism alone. Were it necessary for the support of the argument to arrive at the probable error of the magnetarium results, among others, the following points might be mentioned which would affect them and in regard to which Wilde says nothing.

(1.) The effect on the needles by the earth's magnetic force at the station where the results are ground out.

(2.) The sensible amount, his needles being in proportion to the diameter of the outer sphere as 1 : 9, by which they would be attracted directly or obliquely towards that globe as the

magnetic force on the two ends would be unequal and non-parallel.

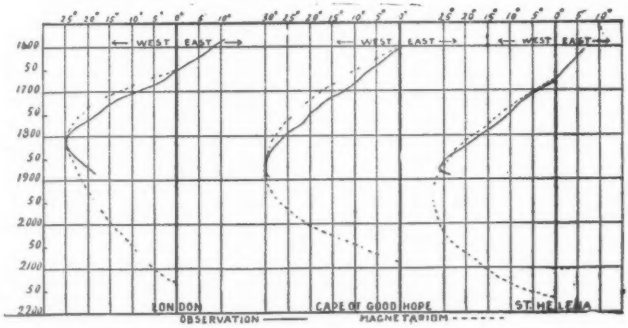
(3.) The needles vibrate over about 10 degrees of terrestrial surface, so that when Wilde measures the declination at say London, he is getting it for the whole of England, over which there is a range of about five degrees.

(4.) The adjustment of the mechanism with reference to maintaining the magnetic pole in latitude 72° with regard to one station alone. It is well known that the magnetic meridians require considerable urging to be made to pass through one point. Besides the latitude of the north magnetic pole is uncertain by at least 1° and probably more, no wholly satisfactory determination of its position having ever been made. Ross made a dash at it in 1831–32 and the International Polar Commission in their comprehensive labors forgot all about this interesting point. This will introduce an uncertainty by at least 2° in the polar inclination of the axis of the internal sphere.

To facilitate the comparison between fact and theory, instead of the table which Wilde gives, we have before us a diagrammatic representation (Diagram A) of all the observations of magnetic declination known for the three stations, London, Cape Town, and St. Helena, and all the results as obtained with the magnetarium, the full curves representing the former, the dotted, the latter. For London our earliest observation is 11° 15′ East in 1580. The march of the declination here has already been pointed out. For Cape Town or Cape of Good Hope, our series begins in 1605 with the needle pointing 0·5° to the East. Marching westward it reaches its maximum westerly elongation about 1870. After hovering here awhile it turned its course and is now diminishing its westerly declination at the rate of 2′ per annum. At St. Helena the observations date back to 1610, the needle pointing about 7° to the East. Crossing the zero line somewhere between 1680 and 1690, it has reached its maximum westerly extreme at the present time and after remaining stationary for a few years will begin to march eastward. The Magnetarium results were ground out separately, beginning in each case with zero declination and continuing until the inner sphere had accomplished one-half of a differential revolution, when the needle pointed again zero, giving thus a half period of secular change. The declination was measured for every 6° of differential motion. The results for London were obtained on the basis of a symmetrical distribution of terrestrial magnetism. It took 60° of differential motion of the globes to produce the maximum westerly elongation. Now from the observations we find that this covers a period of about 160 years, hence 6° of differen-

tial motion are equivalent to 16 years. As, according to Wilde, it would take one complete differential revolution of the inner sphere to produce a complete cycle of secular change, the period of the latter would be $360\times\frac{16}{6}$ or 960 years and the annual rate of retardation of the inner sphere $\frac{360\times60}{960}$ or 22·5 minutes of arc. That is, in the time that the terrestrial or electro-magnetic shell has made $960\times365\frac{1}{4}$ rotations, the vaprous sphere has made one less. Wilde carefully points out

A.



here that the "westerly march of the needle on the magnetic globes as shown in Table II (represented by the dotted curve on diagram A), exhibits similar relations in the period and rate as those in Table I," (represented by the full curve)! He evidently forgot that he had adjusted his mechanism in the first place, so that the maximum declination of 24° 38′ at London would be obtained, hence he only got out wha the put in. London, then, we shall have to put aside and count neither for nor against him.

Before grinding out the next stations, the mechanism undergoes a modification. As a first attempt to approximate to the complex magnetic condition of the earth, Wilde lines the interior of the outer globe under the land areas with sheet-iron to render them more magnetic than the ocean areas. This proves a dead failure. He next reverses his conditions and puts sheet iron below the ocean areas, when, behold, a most remarkable change takes place and most interesting correspondences with facts, as exhibited in the present distribution of terrestrial magnetism, are obtained! But as these properly refer to the distribution of terrestrial magnetism and not to

the secular variation, they cannot be entered upon here. With the apparatus in this condition he gets the secular variation at Cape of Good Hope and St. Helena. It took 102° of differential motion to produce the maximum west at Good Hope. As it had previously been found from the London results that the annual differential motion was 22·5 minutes of arc, 102° would be equivalent to $\frac{102\times60}{22\cdot5}$ or 272 years. From the observations we get about the same interval. Hence, here we have apparently a close correspondence between theory and fact, albeit that there is an average difference of about 3° between the two curves all along and but one point of correspondence actually obtained. It will also be seen from the diagram (A) that by starting about 50 years later, or in other words, if the zero at Good Hope had occurred at the same time as at London, the same maximum westerly elongation of about 25° would have been obtained as at London. It looks very much as though Wilde happened to strike the maximum of 30° instead of 25° because about 50 years more of secular variation had been ground out. But we will let Wilde have this point and proceed to the next station which furnishes the most satisfactory test.

Here he had no means of knowing when the maximum west would set in and what its amount would be and hence would be unbiased. The last recorded observation was in 1846, (23° 11′ W.) indicating that westerly declination was still increasing. In *his* table of observations, Wilde gives 26° 00′ W. for 1880, which, I presume, was taken from the British Admiralty Chart. This is the last that he knew anything about. In 1890, Mr. E. D. Preston, while on the Solar Eclipse Expedition to St. Paul de Loanda, touched at Helena and made magnetic observations. He got an average value of 24·3° for the magnetic declination. Mr. Preston's observations have been published in Bulletin No. 23 of the Coast and Geodetic Survey. Even without the supposititious value of 1880 Prof. Schott, by expressing the magnetic declination in the form of a sine function, has deduced that the maximum occurred about 1890. As a further check, I have examined the excellent magnetic charts for 1885 by Neumayer in Berghaus's Physikalischer Atlas and find for 1885, 25°, showing very clearly that the maximum occurred somewhere between 1880 and 1890. Wilde, as will be seen from the diagram (A) and his table given below, gets the maximum west in 1939, or fifty years later. Hence, here he has failed, but it will be noticed that in this case there is the closest correspondence between the two curves. Let us assume now that the amount of annual retardation and period of a differential revolu-

tion of the inner sphere were unknown and proceed as we did at London to find them. It took 96° of differential motion to produce the maximum at St. Helena, which we have found from observation to have occurred about 1890, covering thus a period from zero of about 208 years instead of 256 as Wilde has it. Hence, instead of 6° being equal to 16 years as at London and Good Hope, we find 6° = 13 years and the total period 60×13 or 780 years instead of 960 and the annual amount of retardation 27·8′ instead of 22·5′! In other words, for London and Cape of Good Hope the inner electro-dynamic sphere must make one complete differential revolution in 960 years, but to accommodate St. Helena it must go at a more rapid gait and perform the complete revolution in 780 years!

The table before us is the one Wilde presents at the end of his second paper, "with the view," as he says, "that they may be of some service to science in the distant future."

Declination periods at London, St. Helena, and the Cape of Good Hope for the cycle of secular changes of the earth's magnetism.

Declination,			London.		St. Helena.		C. of Good Hope.	
			Epoch.	Interval.	Epoch.	Interval.	Epoch.	Interval.
0° outward march		W.	1657–1817	160	1683–1939	256	1609–1881	272
0° return	"	W.	1817–2137	320	1939–2163	224	1881–2089	208
0° outward	"	E.	2137–2457	320	2163–2387	224	2089–2297	208
0° return	"	E.	2457–2617	160	2387–2643	256	2297–2569	272
				960		960		960

It will be seen from this table that the consequences of Wilde's theory are:

(1). That the period of a complete secular change is the same all over the globe—this period being approximately 960 years.

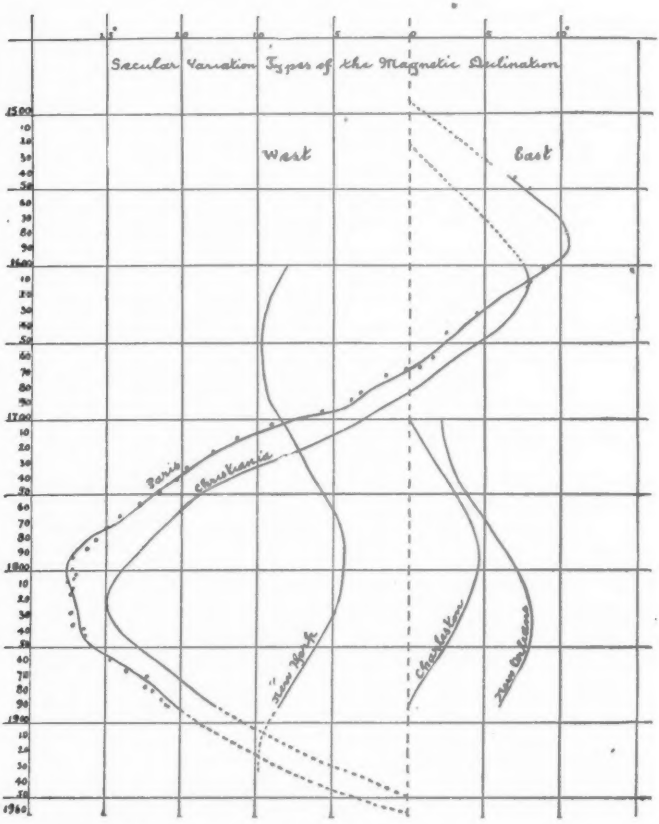
(2). That the declination at every point on the earth, at some time during the cycle, passes through zero.

(3). That the total amounts of easterly and westerly declinations are approximately equal.

How utterly contradictory these three conclusions are to facts and what little reliance can be put upon Wilde's table, will be seen from the next diagram (B) giving Secular Variation Types of the Magnetic Declination. At no station have we record of a complete period. There are a number, however, where the series of observations will warrant our foretelling the length of the period certainly within 50 years. The next half century will witness the completion of several of the American stations. The curves on the diagram, with the exception of Christiania, have all been plotted from the

secular variation expressions given in Prof. Schott's paper, App. 7, Coast and Geodetic Survey Report for 1888. Where the curve extends beyond the recorded observations, it is given in dashes. It is well known that the sine periodic function is well adapted for expressing the secular variation. Such a

B.



function enables you to deduce the period, range, times of maxima and minima, etc. How closely it can be made to agree with actual fact is indicated in the case of the Paris curve, by dots which represent the observations. Here we have the longest and best discussed series, the earliest observation dating back to 1541, over 350 years ago. The next best discussed series is for Christiania by Prof. Weyer.

I shall not be able to point out all the interesting features brought out by this diagram. Only such as will be a direct refutation of Wilde's theory will be touched upon.

(1.) *The period.*—The diagram at once shows not only how far the periods fall short of 960 years, but also, which is the important point, how greatly they differ among themselves.

In the following table I have given some of the periods and ranges. This table alone will overthrow Wilde's theory. From it will be seen that the secular variation period is not a universal one, but is different for every station. So that if

Station.	Period, years.	Range.
Paris*	470	32°
Christiania	420	27
Cape Town	590	30
St. Helena	582	31
Ft. Albany	300	14
St. Johns	347	18
Eastport	288	8
New York City	277	6
Charleston	257	5·5
New Orleans	257	6
Rio de Janeiro	450 (?)	20 (?)

the cause of the secular variation is the differential rotation of an electro-dynamic substance within the earth's crust, then to satisfy every point on the globe it must have every possible rate of rotation, or every station must have its own electro-dynamic sphere roll around in the inscrutable region below us! Is this not tantamount to Barlow's idea that the secular variation at every station could be explained by supposing that each had its own magnetic pole describing an orbit about the rotation pole? But, says Sir John Herschell, if that is so, haven't you renounced the idea of polarity altogether?

(2.) The diagram will show that there are stations where the declination does not cross the zero line, but remains west or east. At New York City, for example, in about 1933 we shall have a full period and there is no question but what the declination remains west. Charleston is mostly east, but crosses the zero line. New Orleans, doubtless, remains east during its whole period. Probably better illustrations of places where the declination remains east will be found with the lapse of time along the Pacific coast. And how unequal the amounts of easterly and westerly declination are about the zero line is abundantly shown by Paris and Christiania.

* The period at London is estimated to be between 500 and 550 years, range 35°.

As this paper might be considered incomplete were no reference made to one or two things which have been brought forward as verifications, I will briefly allude to them. Wilde's next strongest argument to those given above, is a table which gives the westerly progression of the zeros of declination across the Atlantic from 1492–1880, and herein is included that very ancient observation of Columbus where his needle changed from east to west, concerning the exact location of which there has been controversy. All that will be said is that Wilde gives no means for the verification of his figures, as he did at those stations which have been discussed. Furthermore the table has been obtained on the assumption that the inner sphere retreated at the annual rate of 22·5 minutes of arc. It has already been shown that for St. Helena the sphere lagged behind 27′·8 and the table of periods shows that for every point on the globe this rate is different. Again, the points mentioned affecting the accuracy of a determination of the declination on the Magnetarium and from comparisons made between fact and theory wherever possible, it is very much doubted if Wilde can get within 5°—certainly not within 3°. Now when you take into consideration that if the isogonic lines do not cut the meridians or parallels sharply, it can be seen how little reliance can be put upon the determination of geographical position by means of the magnetic declination. Nor need Wilde have gone back to the time of Columbus, where we have absolutely no data, to verify his theory. If he will reproduce in range and period, Paris, Cape of Good Hope, New York City, and St. Johns, conjointly not separately, we will ask no further verification.

The opinion of this paper then is that while Wilde's theory *has* given us a secular variation, it has *not* given us the secular variation as manifested on the earth. Nor has it given us a better representation than the old theory of a uniformly revolving magnetic pole. Furthermore, have we not taken a step backward? If we go back to Halley, two centuries ago, we find the idea embodied in Wilde's mechanism, expressed in all detail and without any difference worth mentioning. A full description of Halley's theory* can be found in Harris' Rudimentary Magnetism. We are obliged then to characterize the Magnetarium as nothing more than an improved Barlow globe, and in conclusion we will say with Halley that the "secular period and motion are secrets as yet utterly unknown to mankind, and reserved for the industry of future ages."

* Originally given in Philosophical Transactions of the Royal Society for 1683, p. 208 and for 1692, p. 563.

Art. LXIII.—*Josephinite, a new Nickel-Iron;* by W. H. Melville.

History.—Several months ago Prof. F. W. Clarke submitted to me for examination a quantity of magnetic pebbles which were sent to this office by Mr. Wm. H. Hampton of Portland, Oregon, and by subsequent correspondence with this gentleman he obtained a larger amount with full liberty to publish the results arrived at in the laboratory.

In the spring of 1891 Mr. Hampton discovered these pebbles in large quantities in the placer gravel of a stream in Josephine and Jackson Counties, Oregon, which border on the south of Douglas Co. where the nickel silicate* described by Prof. Clarke occurs. He analyzed with reference to nickel and iron an average sample of twenty pounds of the wash gravel from the placer diggings, and found that the metallic portion gave 60·3 per cent nickel and 26·7 per cent iron. From the nature of the gangue or stony portion Mr. Hampton concluded that these waterworn pebbles and bowlders—for some pieces weighed over one hundred pounds—"came from an eruptive dike somewhere in the vicinity." The locality of this dike was not at that time ascertained.

Physical Characters.—The pebbles are irregular in shape but approximate the form of ellipsoids. Their smooth surfaces, polished by the action of water, are colored in general greenish black, interrupted by bright areas of the grayish white alloy of nickel and iron. The former portions consist of siliceous matter and when cut by a knife yield a dull and light gray powder, but broken fragments show greenish yellow and deep green colors and resinous luster resembling noble serpentine. With this is associated in some pebbles a silicate whose hardness is between 5 and 6. It is compact and on the fresh fracture exhibits a light brown color and vitreous luster, while exposed surfaces are reddened by ferric oxide.

The texture of the metallic portion as it appears on fracture is granular. The metal is gray, malleable and sectile with hardness about 5.

The specific gravity of one lot containing forty-two pebbles was taken in a pycnometer at a temperature of 22° C. These pebbles ranged in weight from 0·3159 to 1·6447 grams and were about the dimensions of a pea. The largest pebble in my possession weighed 4·2847 grams, and the specific gravity of this was made by suspending it from a silk fiber. Two determinations furnished a mean specific gravity of 6·204.

* Bulletin No. 60, U. S. Geol. Survey, p. 21, 1887–1888.

The pebbles are strongly magnetic.

Analyses.—The analyses were conducted with the aim of separating the pebbles into their proximate principles and also their ultimate constituents. Two different lots of about twelve grams each were pulverized in a steel mortar, a delicate and tedious operation owing to the extreme malleability of the nickel-iron. Two complete analyses of these samples were made. The ratio between the nickel and iron in the metallic state was ascertained by deducting from the total amounts of each of these elements those quantities which were found in other combinations. The ordinary method of fusion with sodium hydrate and subsequent treatment of the residue with concentrated nitric acid failed to give the true contents of the metallic portion in the pebbles, because the nickel-iron was not passive in this acid. The ratio between the nickel and iron, however, could be obtained by this method.

The stony matter was freed as far as practicable from the magnetic parts by a fractional process, that is to say by the repeated use of an electro-magnet and by the decantation of the light particles suspended in water. The siliceous portion was then analyzed. A fresh sample was treated with diluted hydrochloric acid, and after repeated evaporations the soluble silica was separated from the insoluble residue and weighed. The insoluble residue was analyzed, and the percentage composition of soluble silicate was inferred from this analysis, the analysis of the total siliceous matter, and the total silica of the pebbles.

The mean composition of the pebbles is shown by the following numbers:

	Per cent.		Per cent.
Nickel free, Ni	60·45	Nickel combined	0·25
Cobalt, Co	0·55		
Iron free, Fe	23·22	Iron combined	1·79
Pyrrhotite, Fe_2S_2	0·55	Sulphur	0·22
Chromite, $FeO.CrO_2$ / Magnetite, $FeO.Fe_2O_2$	0·12	Chromium	0·04
Copper, Cu	0·50		
Arsenic, As	0·23		
Chlorine, Cl	0·04		
Silicate (anhydrous)	12·26		
H_2O below 100° C.	0·81		
H_2O above 100° C.	1·12		
CO_2	trace		
Volatile matter	0·70		
	100·55		

Per cent in pebbles.	Total silicate.	Insoluble silicate.	Soluble silicate.
SiO_2	5·14	0·23	4·91
Al_2O_3	0·33	0·03	0·30
Fe_2O_3	2·08	0·04	2·04
(Ni,Co)O	0·32	trace	0·32
CaO	1·62	0·06	1·56
MgO	2·69	0·14	2·55
Na_2O	0·08	----	0·08
H_2O above 100° C.	1·12	----	1·12
	13·38	0·50	12·88

Composition.	Insoluble silicate. Per cent.	Insoluble silicate. At. ratio.		Soluble silicate. Per cent.	Soluble silicate. At. ratio.	
SiO_2	45·63	3·04		38·23	2·55	
Al_2O_3	6·58	0·39		2·34	0·14	0·74
Fe_2O_3	8·77	0·33		15·88	0·60	
(Ni,Co)O	undetermined		2·51	2·49	0·07	
CaO	11·03	0·39		12·14	0·43	
MgO	28·01	1·40		19·85	0·99	2·47
Na_2O	----			0·35	0·01	
H_2O above 100° C.,	----			8·72	0·97	
Total	100·02			100·00		

Silicates.—There are two silicates, then, the one soluble in hydrochloric acid being undoubtedly serpentine. This serpentine surrounds the metallic portion, and on polished sections its deep green color is well brought out. It has not penetrated into the metallic mass, and it would appear that the pebbles once formed a large aggregation and that fractures took place in directions of least resistance through the serpentine. Other characters of serpentine were noted, its resinous luster, its hardness of about 3, and its infusibility. In the closed tube water was given off. The atomic ratio of the combined bases and water to silica is 3·2 : 2·55 or 5 : 4, a ratio which is identical with that of serpentine. The ratio between bases and water, 7 : 3 instead of 3 : 2, is not the true ratio for these constituents in serpentine as it exists in the pebbles, because the analysis is calculated from figures obtained from material which was dried at 100° C. Again the reddish brown coloration of this dried material indicated the presence of some impurity, probably oxides, and this could not be eliminated. The water is, therefore, too low and the iron oxide too high.

The insoluble silicate, however, cannot be so clearly made out. Its atomic ratio, SiO_2 : base = 6 : 5, brings it nearer an orthosilicate than a metasilicate. It is light brown, vitreous, hard, compact and not cleavable. It does not fuse before the blowpipe. It is not so hard as olivine and its insolubility in acid

excludes this mineral. In physical and pyrognostic characters and to some extent, also, in composition it agrees fairly with bronzite (enstatite). The probable silicates to occur in this association are pyroxene, olivine, enstatite, from which serpentine is derived, while a feldspar is not to be expected. I did not determine to which silicate the sodium-oxide belonged, owing to its small quantity and the small quantity of insoluble silicate in the pebbles. A mixture of a soda-lime feldspar and enstatite (or pyroxene) would answer the requirements of the ratio, but this is purely speculative. So far as the data go it is best to regard this silicate as an impure bronzite.

During attempts to purify the silicates it was noticed that on the removal of the metallic part by a neutral concentrated solution of either cupric sulphate or mercuric chloride that the silicate was more or less attacked. Magnesia was removed, and one analysis showed that out of 2·69 per cent MgO in the pebbles only 0·43 per cent remained in the purified silicate. Curiously no iron or lime was removed. Pulverized olivine and serpentine were each digested with copper sulphate on the water bath two or three hours; a yellow copper salt was deposited and a large quantity of magnesia was taken out of both silicates. A basic copper sulphate was produced, and the liberated sulphuric acid (SO_3) combined with magnesia to magnesium sulphate. In the presence of olivine or serpentine this treatment for the purification of the silicate is inadmissible.

Chromite.—Under the microscope a minute quantity of black metallic grains can be seen in the siliceous portion, which do not precipitate copper from a sulphate solution. These grains consist of chromite with a very few strongly magnetic particles of magnetite. 0·04 per cent of chromium was found in the pebbles, while the per cent of chromium corresponding to 0·12 per cent of chrome iron is 0·036. The presence of chromite is naturally expected in the serpentine.

Magnetite.—The few grains mentioned under chromite were dissolved by protracted heating in hydrochloric acid. Other particles of magnetite were not recognized with certainty.

Two magnetic pebbles were found among those which carried the large percentage of nickel, and a small amount of fibrous serpentine (not chrysotile) adhered to this magnetite. It is probable that magnetite occurs in the original deposit from which the nickel pebbles were transported. The high percentage of iron obtained by Mr. Hampton was probably due to the presence of some magnetite-pebbles in the average sample which he studied.

Pyrrhotite (*Troilite*).—The monosulphide of iron could not be separated from the other principles with sufficient purity for analysis. The amount of this mineral, formula Fe_7S_8, was

calculated from the total sulphur, 0·22 per cent. Hydrogen sulphide was liberated in considerable quantity when the powdered pebble was treated with diluted chlorhydric acid. Millerite does not act thus.

Copper.—The copper is not a constituent of the pyrrhotite, but belongs to the nickel-iron. Copper minerals were not detected under magnifying power.

Arsenic.—Arsenious oxide was condensed in the cool parts of a tube through which air was allowed to pass, as also in all the tubes used for the determination of volatile matter. No sulphide of arsenic dissolved by digesting in the cold with ammonium carbonate, nor could niccolite (nickel arsenide) be detected. Arsenic forms a part of the metallic portion of the pebbles.

Chlorine.—The chlorine was determined in a nitric acid solution of the original powder, a blank experiment with the use of the same quantity of reagents being run parallel with that. In an aqueous solution were found iron, nickel, magnesium, sodium and chlorine, and this fact together with the small available quantity of chloride caused the difficulty in determining to which element chlorine was combined. The presence of iron and nickel, since pyrrhotite carries nickel, can be accounted for in the aqueous solution by the easy oxidizability of the sulphuret with free access of air. Green ferrous chloride could not be detected in the powder, nor any soluble salt possessing that color. The permanence of the pebbles in air is also a presumption in favor of the absence of lawrencite. Nickel chloride has not before been observed, but may possibly exist in these specimens. It is more probable that the chlorine is united with sodium 0·04 per cent requiring 0·026 per cent Na or 0·035 per cent Na_2O. The magnesium is in the form of carbonate

Water and Volatile Matter.—The powdered substance in a platinum boat was heated in a glass tube in a stream of dry carbonic anhydride, and the water, both hygroscopic moisture and water of constitution, was weighed in a chloride of calcium tube. Another portion was heated in hydrogen gas, and hence the oxygen in the oxides was known, although this amount might have included some, if not all, of the oxygen combined with iron in the ferric state in the silicates. After burning in a current of dry air and then reducing in hydrogen the total loss was ascertained from the difference in weight of the contents of the boat before and after the operation. In all cases except when burnt in air a brownish cloud possessing an empyreumatic odor was driven off without leaving a brown black sublimate in the tube. It was a volatile organic substance whose nature was not discovered. The pulverized peb-

bles when treated with dilute hydrochloric acid at the temperature of the water bath gave the odor characteristic of the decomposition of a carbide, so that the volatile matter given in the analysis consists of organic matter, namely combined carbon and probably a hydrocarbon. All loss arising from the volatilization of arsenic, sulphur and chlorine have not been included in the per cent given for volatile matter.

Nickel-Iron.—Of special interest is the metallic portion.

		(1)	(2)	At. ratio.
Two analyses gave:—	Fe	23·36	23·09	0·41
	Ni	60·47	60·43	1·03

From this ratio is deduced the formula Fe_2Ni_5.

The following table gives a comparison of a few examples of nickeliferous iron which form an instructive series:

	Catarinite.*	Octibbehite.†	Awaruite.‡	Josephinite.
Iron	63·69	37·69	31·02	23·22
Nickel	33·97	59·69	67·63	60·45
Atomic Ratio F: Ni	1·14 : 0·58	0·66 : 1·02	0·55 : 1·17	0·41 : 1·03
Formula	Fe_2Ni	Fe_2Ni_3	$2(FeNi_2)$ Fe_2Ni_4	Fe_2Ni_5

The question naturally arises whether the origin of these pebbles is cosmic (meteoric) or terrestrial. Catarinite and octibbehite have been considered meteoric falls, while awaruite has been traced from the drift in the Awarua river on the western side of the middle island of New Zealand to a "mountain of peridotite, an olivine-enstatite rock more or less serpentinized," and is undoubtedly terrestrial. In the drift are found gold, platinum, cassiterite, chromite and magnetite. The placer gravel, in which josephinite is found, is like that of New Zealand with the exception of the occurrence of platinum§ and cassiterite so far as known at present.

There is one element, phosphorus, which is almost universally found in meteorites and combined with nickel and iron to form the mineral schreibersite, which has no representative among terrestrial minerals. After evaporating to dryness a nitric acid solution of a sample of the pebbles, and fusing the residue with sodium carbonate and potassium nitrate, phosphoric acid was not detected in the acid filtrate, and thus was

* Encyclopédie chimique, Fremy, Metalloids, Tome ii, par M. Stanislas Meunier.

† This Journal, II, xxiv, p. 293, Taylor.

‡ This Journal, vol. xxxiii, p. 244, G. H. F. Ulrich; analysis by W. Skey. A. Sella described a nickel-iron from the auriferous sands of the stream Elvo, near Biella Piedmont; Fe 26·6 per cent; Ni(Co) 75·2 per cent; formula $2(FeNi_2) = Fe_2Ni_5$. C. R. cxii. 171; also this Journal, III, p. 252, 1891.

§ Platinum occurs in the region of Rogue river, Oregon.

proved the absence of phosphorus both as terrestrial phosphate and meteoric phosphide. In the published analysis of awaruite by W. Skey no phosphorus is given. Catarinite and octibbehite contain 0·05 per cent and 0·10 per cent respectively.

By etching with nitric acid Widmannstätten figures cannot be produced upon a polished surface of the nickel-iron. The metal seems to be homogeneous, and the little sulphide to occur in the fissures. Awaruite is passive toward an acid solution of copper sulphate, and only with difficulty and long heating is the nickel-iron from Oregon completely dissolved with replacement of the copper in a sulphate solution. This passive state is uncommon with the ordinary nickel-iron of meteorites, but the high percentage of nickel may account for this property. Concentrated nitric acid dissolves the alloy.

Daubrée* points out that meteorites and analogous terrestrial rocks differ in that the former contain in a reduced state certain substances which appear in the latter in the state of oxides. This idea could be extended to include metamorphism in its broadest sense. Serpentine is rarely found in meteorites, although Wöhler has recognized it in some carbonaceous meteorites. In the two cases of awaruite and josephinite, serpentine is the principal silicate derived in the former from olivine and enstatite. Daubréelite is metamorphosed into chrome-iron, and this may possibly be the explanation of the origin of the latter, that the double sulphide of chromium and iron existed in the ferro-magnesian silicates before or at the time of their serpentinization, and was then oxidized to chromite.

The evidence cited in the previous paragraphs points to the terrestrial origin of the pebbles which form the subject of this paper, and here the question of origin must rest till the nickeliferous iron is found in *situ*.

The name josephinite is given in honor of the county, its locality, in accordance with the custom in use for naming analogous substances.

Laboratory, U. S. Geological Survey, March, 1892.

ART. LXIV.—*A Fibrous Intergrowth of Augite and Plagioclase, resembling a reaction rim, in a Minnesota Gabbro;* by W. S. BAYLEY.

IN the course of an investigation into the microscopical characteristics of the gabbro forming the great flow, or flows, near the base of the Keweenawan series of rocks in north-

* Etudes Synthétiques de Géologie Expérimentale par A. Daubrée, 1879, p. 578.

eastern Minnesota,* the attention of the writer was repeatedly attracted by a fibrous growth around olivine, that resembles very strongly the reaction rims that have been described as existing between garnet and serpentine by Schrauf† and Becke,‡ between garnet and olivine by Diller,§ and between the last named mineral and feldspar by Tornebohm,‖ Julien,¶ Becke,** G. H. Williams,†† Schuster,‡‡ Teall,§§ and Lacroix‖‖ A close study of the phenomenon, however, disclosed the fact that the growth is not due to reactionary processes between the rock's constituents, but is simply an original intergrowth of two of them. Its appearance, nevertheless, is so suggestive of a reactionary origin (see fig. 1), that it has been thought well to describe it briefly.

The rock in which the phenomena occur is a very coarse grained gabbro, composed of a perfectly fresh olivine with the composition of hyalosiderite, a pink or purple diallage and labradorite, whose analysis yielded Dr. Hillebrand the following figures:

SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	H_2O	Total
51·89	29·68	0·32	0·37	12·62	0·38	0·50	3·87	0·46	=100·09

Its structure is typically gabbroitic, in that the *plagioclase* is the youngest of the three components, and not the *pyroxene*, as in the case of the diabases.¶¶ It is peculiar, however, in the fact that in most sections the diallage, instead of occurring in grains and plates scattered indiscriminately among the other constituents, exhibits a fondness for the proximity of the olivine. As illustrated in figure 2 (specimen from the Falls of the Cloquet River, SE¼ Sec. 34, T. 53 N., R. 14 W.) the diallage envelops the olivine grains and so separates them from the surrounding plagioclase It is evident that the first mineral to form from the magma was olivine. Then followed the pyroxene, which attached itself to the surfaces of the

* R. D. Irving: Copper-Bearing Rocks of Lake Superior: Mon. v, U. S. G. S., p. 266; this Journal, III, vol. xxxiv, 1887, p. 204 and 249; and 7th Ann. Rept. U. S. G. S., 1888, p. 419.

† Neues Jahrb. f. Min., etc., 1884, ii, p. 21, and Zeitschr. f. Kryst., vi, p. 321.

‡ Min. u. Petr. Mitth., iv, pp. 189, 285, 323–6.

§ This Journal, xxxii, 1886, p. 122.

‖ Neues Jahrb. f. Min., etc., 1877, pp. 267 and 384.

¶ Geology of Wisconsin, III, p. 235 and Plate XXII.

** Min. u. Petrog Mitth., 1882, iv, pp. 330, 350, 450.

†† Bull. U. S. Geol. Survey, No. 28, p. 52.

‡‡ Neues Jahrb. f. Min., etc., B. B. v, p. 451.

§§ Min. Magazine, Oct., 1888, p. 116.

‖‖ Bull. Soc. Franc d. Min, 1889, xii, p. 83.

¶¶ So far as the knowledge of the writer extends the rock of this flow is the only true gabbro in northeastern Minnesota. The other coarse-grained pyroxene-plagioclase rocks of this region, described by Irving and others under the name of gabbro, are either diabases or diabase-porphyrites.

olivine grains and continued to grow until it had abstracted all pyroxenic material from the still liquid mass. The residue solidified as labradorite. When the diallage is present in the rock in large amounts it completely envelopes the olivine; when it is present in small quantity only, it forms a very narrow rim that may or may not surround the older mineral. Although the association of olivine and diallage is not as described in all sections, it is sufficiently common in the rock to emphasize the tendency of the latter to arrange itself around the former.

1.

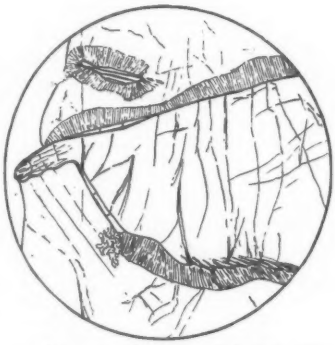


FIG. 1. Olivine and biotite surrounded by fibrous growths resembling reaction rims. Section 7025. ×30.

2.

FIG. 2. Section of olivine-gabbro, exhibiting the tendency of the pyroxene to include olivine grains. Section 1103. ×20.

In one-third of the sections of this rock studied, the olivine grains, where they would otherwise come in contact with plagioclase, are kept from doing so by a finely fibrous growth that polarizes in some places with bright colors, and in others with the bluish-gray tint of thin feldspar. Though in general these fibers extend perpendicularly from the bounding surfaces of the olivines, they occasionally form radial groups centering at points near the peripheries of the surrounded mineral. Nor are the fibers in all cases continuous. They often branch and fork, and frequently stop suddenly at short distances from their points of origin, while new fibers begin their courses just beyond. This fibrous envelope, moreover, is not confined exclusively to the vicinity of olivine. It is found also around decomposed biotite (see upper left hand corner of fig. 1) and around grains of magnetite (fig. 3).

A close inspection of the sections often reveals the presence of an intermediate zone between the fibrous one and the min-

eral surrounded by it. This is very narrow and consists of a highly refractive substance with strong double refraction (figs. 1 and 3). This zone is too narrow to admit of the nature of its material being discovered by its optical characteristics; but every gradation can be traced between wide enveloping mantles of diallage and thin seams with all of the characteristics of the intermediate zone. Moreover, it is frequently noticed

3.

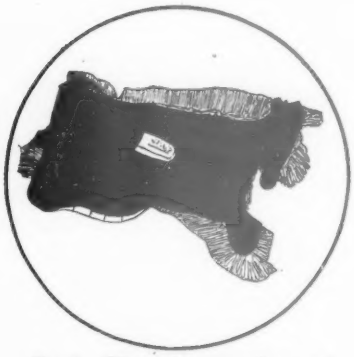


FIG. 3. Fibrous intergrowth around magnetite? Between the latter mineral and the fibrous rim can be seen a narrow zone of diallage. Section 10,439. × 20.

4.

FIG. 4. Olivine partly surrounded by narrow rim of augite, which is continuous with large plate of same mineral. 8803. × ca. 18.

that the narrow rim widens out and expands into large wedge-shaped plates of whose diallagic nature there can be no doubt (fig. 4). Since the narrow zones between the fibrous envelope and the surrounded minerals are similar in every respect to these narrow rims of pyroxene, it is safe to assume that the former, like the latter, are composed of diallage. Consequently, the fibrous growth, if it be a reaction rim, is one between pyroxene and plagioclase, rather than between olivine and feldspar, as in the cases referred to in the opening paragraph of this article. But the intergrowth is rarely found around well developed diallage plates, while on the other hand it occasionally occurs around olivine, biotite and magnetite without the intervention of the seam of augite between these minerals and their envelope, and, again, it is sometimes found in the midst of feldspar as little granophyre-like bunches, not associated with any iron-bearing mineral whatsoever. It is thus quite evident that the fibrous growth is not a reaction rim between diallage and plagioclase, and, since it occurs indiscriminately around so many different minerals, that it is not a reaction rim at all.

For evidence as to the nature of the constituents of the intergrowth an appeal must be made to the fibrous growth itself. But this is not as satisfactory as it might be, for the fibers in most cases are so fine that nothing more definite can be detected in the rim than an intergrowth of two distinct substances. In instances where its fibrous structure is less well developed, and its components are coarser, the two minerals composing the rim are seen to differ in their colors between crossed nicols, as already indicated. One of these is in long narrow stringers, with club-like extremities. It appears to be continuous with the plagioclase on one side of it and to extend between similar tongues of a more highly refractive substance that spring from the opposite side. It is occasionally marked by twinning bars that are continuations of those existing in the surrounding plagioclase, and it extinguishes simultaneously with the latter. It is undoubtedly plagioclase.

The more highly refractive mineral intergrown with the feldspar is occasionally in such coarse fibers that its augitic character cannot be questioned. In the section of rock No. 8800,* for instance, a large grain of olivine is penetrated by two lath-shaped crystals of plagioclase. Between the feldspars and the olivine is a very narrow rim of augite, while perhaps half of the material within the outlines of the crystals consists of the fibrous intergrowth. On the side of the intergrowth toward the augitic rim, its highly refractive component assumes such broad dimensions that diallagic characteristics may be traced in it, far beyond the points where it leaves the rim to form prolongations between the plagioclase fibers. Fig. 5 illustrates a case in which augite sends out into the plagioclase in which it is imbedded, long pseudopodia-like tongues. Many other instances like the last might be cited to show the tendency of the diallage to form intergrowths with the plagioclase, but enough has already been written to emphasize the point.

5.

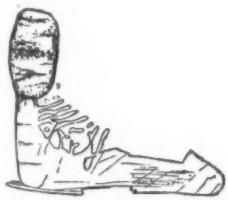


FIG. 5. Augite plate and olivine grain in plagioclase. The augite in the bend extends out into the feldspar, giving rise to an intergrowth, very like that of the fibrous rim. 8803. × ca. 20.

It is true that there is no absolute proof that the highly refractive substance of the fine fibrous intergrowths is identical with the material of the coarse prolongations just mentioned, but the series of gradations between the mantles surrounding olivine and the fibrous intergrowth is

* All numbers of rocks refer to the series belonging to the Lake Superior Division of the U. S. Geological Survey.

so complete (Figs. 2, 4, 5 and 1), that the inference is justified that the highly refractive component of this intergrowth is diallage. In the coarse-grained gabbros the mantle around the olivine is certainly diallage; in those cases where a very thin seam is interposed between the fibrous growth and the mineral it envelops, the material of this seam is as surely a pyroxene. Moreover, the augite of the rock frequently sends out prolongations of its own substance into the surrounding plagioclase, and the ends of these prolongations have characteristics that are identical with those of the more highly refractive component of the intergrowths. Finally, in the coarser rims, their constituents may be traced on the one side into plagioclase and on the other side into diallage.

We may safely infer, therefore, that the fibrous intergrowth, which so closely resembles a reaction rim between olivine and plagioclase, but which is surely not such, is merely a granophyric aggregate of plagioclase and pyroxene. The major portion of the latter mineral in the rock separated before the feldspar, and taking advantage of the surfaces afforded by the already formed olivine and magnetite, fastened upon them. But in many cases, before the crystallization of the pyroxene had ceased, the feldspar began to form, and the two minerals crystallized together micropegmatitically.

So far as known to the writer, only one other description of a similar intergrowth of augite and plagioclase in a manner resembling a reaction rim is to be found in petrographical literature. In 1887 Camerlander* mentioned the existence of such an intergrowth around garnets in a contact rock from near Prachatitz in the Bohemian Forest. The original description has not been seen, but in a review of it by Becke,† words are used that might well be applied to the phenomenon observed in the Minnesota rock: "Especially are the garnets often surrounded by the micropegmatitic intergrowth of augite and plagioclase. This varies remarkably in its appearance from that of undoubted augite imbedded in feldspar, to that of a dense radial bundle of fibres which resembles the kelyphite rims around garnets in serpentine."

United States Geological Survey,
Lake Superior Division.

* Jahrb. d. K. K. geol. Reichsanst. xxxvii. p. 117.

† "Besonders die Granaten sind häufig durch solche mikropegmatitische Verwachsungen von Augit und Plagioklas umrandet. Dieselbe variire ausserordentlich in ihrer Ausbildung von deutlichen in Feldspath eingewachsenen Augits bis zu radial gestelten dichter Faserbüscheln, welch an die Kelyphitranden der Pyrope von Serpentin erinneren." Ref. Neues Jahrb. f. Min., etc., 1888, ii, p. 54.

ART. LXV.—*A Method for the Determination of Barium in the presence of Calcium and Magnesium;* by F. W. MAR.

[Contributions from the Kent Chemical Laboratory of Yale College—XIV.]

THE recent investigation* by Prof. R. Fresenius of the value of the various methods which have been proposed for the separation of barium and calcium, shows that but two of the methods tested by him are sufficiently accurate for good analytical work, and even with these it is necessary to make two treatments in order to obtain a complete separation. The method here described may therefore be of interest and by reason of its rapidity and accuracy may prove valuable, although since the publication of the work of Fresenius another method† has been published from this laboratory which, in point of accuracy, leaves little to be desired.

It has long been known that barium chloride is insoluble to a marked degree in concentrated hydrochloric acid, but the difficulty of filtering off the strong acid has in the past prevented the determination of the exact amount of this insolubility, and for the same reason the reaction has not been available for quantitative use. Since the invention of the Gooch crucible, however, the treatment of such strong acid filtrates has become a matter of the greatest ease, and it seemed worth while to investigate the limits of the insolubility of barium chloride in the strong acid and to ascertain whether the reaction might not be of use in the separation of barium from calcium and magnesium, the chlorides of which are soluble in the strong acid.

The barium chloride used in the following experiments was the pure crystallized chloride containing two molecules of water. The calcium salt was the pure fused chloride, and the magnesium salt was the pure crystallized magnesium chloride dried at 50° C. As the two latter were not determined in the experiments it was not necessary to know the composition of the salts used as regards hygroscopic moisture. Attention was first given to determining the solubility of barium chloride in hydrochloric acid.

SERIES A.

Exp.	$BaCl_2.2H_2O$	Water.	HCl.	Total filtrate.	$BaCl_2$.	Loss.
1	0·5024 grm.	5 cm³	20 cm³		0·4241 grm.	0·0041 grm.
2	0·5084 "	5 "	20 "		0·4304 "	0·0030 "
3	0·5099 "	2 "	25 "		0·4320 "	0·0027 "
4	0·5033 "	2 "	25 "	90 cm³	0·4251 "	0·0039 "
5	0·5047 "	2 "	25 "	52 "	0·4247 "	0·0055 "
6	0·5065 "	2 "	50 "	115 "	0·4257 "	0·0060 "
7	0·5008 "	2 "	50 "	75 "	0·4218 "	0·0051 "
8	0·5011 "	2 "	50 "	93 "	0·4220 "	0·0051 "
9	0·5024 "	2 "	75 "	123 "	0·4246 "	0·0037 "

* Zeitschrift für anal. Chem., XXX, 595.

† P. E. Browning, this Journal, vol. xliii, p. 314.

The experiments in Series A were made as follows:—The barium salt was weighed out, placed in a small beaker and dissolved in the amount of water indicated. The barium was then precipitated as the anhydrous chloride by adding, gradually at first, the amount of hydrochloric acid shown. After standing for five or ten minutes the precipitates were filtered off upon asbestos in Gooch crucibles, washed with concentrated hydrochloric acid, dried sometimes over a low flame (at about 150°–200° C.) and sometimes in an air bath heated to 165° C. and weighed. In several cases the total filtrate was measured and the volume is given in the tabular statement. The results show a considerable solubility amounting to about 1 part in 8000 under the conditions given.

SERIES B.

Exp.	$BaCl_2.2H_2O$	Water.	HCl.	Total filtrate.	$BaCl_2$.	Loss.
10.	0·5057 grm.	2 cm³	25 cm³	75 cm³	0·4268 grm.	0·0042 grm.
11.	0·5017 "	5 "	50 "	90 "	0·4198 "	0·0078 "
12.	0·5068 "	3 "	50 "	100 "	0·4235 "	0·0085 "
13.	0·5019 "	2 "	100 "	144 "	0·4186 "	0·0082 "

The experiments in Series B were conducted similarly to those of Series A except that the precipitates were allowed to stand 24 hours before filtration. The loss due to solubility was, as is shown by the table, greater than before, due doubtless to the escape of hydrochloric acid gas from the solution.

SERIES C.

Exp.	$BaCl_2.2H_2O$	Water.	HCl.	Alcohol.	$BaCl_2$	Loss.
14.	0·5011 grm.	3 cm³	25 cm³	15 cm³	0·4228 grm.	0·0043 grm.
15.	0·5096 "	2 "	25 "	10 "	0·4278 "	0·0066 "

The experiments of Series C were conducted in the same manner as those of Series A except that the amount of absolute alcohol indicated was added after the precipitation by hydrochloric acid. The results show that the alcohol neither decreased nor increased the amount of the solubility of the chloride.

SERIES D.

Exp.	$BaCl_2.2H_2O$	HCl.	$BaCl_2$.	Loss.
16.	0·5019 grm.	50 cm³	0·4249 grm.	0·0029 grm.
17.	0·5020 "	50 "	0·4257 "	0·0022 "
18.	0·5020 "	50 "	0·4255 "	0·0024 "
19.	0·5016 "	50 "	0·4259 "	0·0017 "
20.	0·5022 "	50 "	0·4267 "	0·0014 "

In the experiments of Series D the weighed barium chloride was placed in an Erlenmeyer beaker and dissolved in four or five cubic centimeters of water. The indicated amount of acid

was then added, and a stream of hydrochloric acid gas was passed for two hours into the cooled mixture. The precipitates were then treated as in the former experiments. The results show that even in the strongest possible solution, at the ordinary temperature, of hydrochloric acid barium chloride is soluble to a considerable degree, this solubility amounting according to the first three experiments of the series to about one part in 20,000. In Exp. 18 and 19 ten cubic centimeters of absolute ether were added to the solution before passing in the hydrochloric acid gas. The results showed that the ether seemed to decrease the solubility of the barium salt, and therefore the experiments of the following series were undertaken.

SERIES E.

Exp.	$BaCl_2 . 2H_2O$.	HCl.	Ether.	$BaCl_2$.	Loss.
21.	0·5008 grm.	50 cm³	10 cm³	0·4267 grm.	0·0002 grm.
22.	0·5002 "	50 "	10 "	0·4257 "	0·0007 "
23.	0·4999 "	50 "	10 "	0·4252 "	0·0009 "
24.	0·4999 "	50 "	10 "	0·4258 "	0·0003 "
25.	0·5003 "	25 "	25 "	0·4259 "	0·0005 "
26.	0·5002 "	25 "	5 "	0·4262 "	0·0002 "
27.	0·5099 "	25 "	5 "	0·4344 "	0·0003 "
28.	0·5003 "	25 "	5 "	0·4261 "	0·0003 "

The experiments of Series E were conducted as follows. The amount of barium salt specified was dissolved in the least, convenient, amount of hot water (about 2 cm³) and precipitation was brought about by adding the indicated amount of concentrated hydrochloric acid. The beaker containing the precipitate was then placed in cold water and the amount of ether shown in the tables was added and mixed with the solution by thorough stirring. After standing for five or ten minutes the precipitate was filtered off and washed with concentrated hydrochloric acid containing about ten percentum by volume of absolute ether and dried, sometimes in an air bath at 165°–175° C. and at others over a radiator giving a temperature of 175°–200° C. A constant weight was more quickly obtained by the latter method and it was used exclusively in the experiments of the subsequent series. In using it a low heat was used at first and the temperature was not increased until the precipitate was moderately dry. The results show that barium chloride is practically insoluble in a mixture of hydrochloric acid and ether containing about one-sixth by volume of the latter. The average solubility calculated from the experiments given is one part in 122,000. The actual solubility is less than this since no account was taken of the volume of the washings which were at least equal to the original filtrates.

SERIES F.

Exp.	$BaCl_2.2H_2O$.	$CaCl_2$.	HCl.	Ether.	$BaCl_2$.	Loss.
29.	0·5001 grm.	0·5 grm.	50 cm³	10 cm³	0·4250 grm.	0·0013 grm.
30.	0·4999 "	0·5 "	50 "	10 "	0·4250 "	0·0011 "
31.	0·5005 "	0·5 "	25 "	25 "	0·4260 "	0·0006 "
32.	0·5002 "	0·42 "	25 "	5 "	0·4258 "	0·0004 "
33.	0·5001 "	0·5 "	25 "	5 "	0·4255 "	0·0008 "
34.	0·5005 "	0·5 "	25 "	5 "	0·4251 "	0·0015 "
35.	0·5001 "	0·5 "	25 "	5 "	0·4254 "	0·0009 "
36.	0·5001 "	0·5 "	25 "	5 "	0·4258 "	0·0005 "
37.	0·5003 "	0·5 "	25 "	5 "	0·4261 "	0·0004 "
38.	0·1002 "	3·0 "	25 "	5 "	0·0842 "	0·0010 "
39.	0·0107 "	3·0 "	25 "	5 "	0·0080 "	0·0005 "
40.	0·5100 "	0·5 "	25 "	....	0·4328 "	0·0020 "

Series F was undertaken to test whether the mode of precipitating barium used in the preceding series would be of use in the separation of the barium from calcium. The experiments were conducted as in Series E, except that the calcium salt was dissolved with the barium chloride. It was necessary to use more water than in Series E to effect solution, but as the barium salt was uniformly the last to dissolve the effect was practically the same as before. The results show that mixtures of barium and calcium in all proportions are perfectly separated by this method, 0·010 grm. of barium chloride being separated with accuracy from 3 grm. of calcium chloride. The calcium does not show the slightest tendency to come down with the barium, and those experiments in which separation was effected by the use of 25 cm³ of hydrochloric acid and 5 cm³ of ether gave rather better results than those in which double this volume was employed. It is better not to let the precipitations stand too long before filtration, even if kept cold, as the hydrochloric acid evaporates from the solutions, and experiments in which filtration was delayed for about two hours (e. g., Exps. 33, 34, 35) show a rather larger loss than the average. That there is no advantage in increasing the amount of ether over the proportions used above is shown by Exp. 31 which is comparable with Exp. 25. In the case of Exp. 40, in which no ether was used the result is comparable with the experiments of Series A. The precipitate was washed, however, with the mixture of hydrochloric acid and ether.

SERIES G.

Exp.	$BaCl_2.2H2O$.	$MgCl_2.6HO_2$.	HCl.	Ether.	$BaCl_2$.	Loss.
41.	0·4999 grm.	0·5 grm.	25 cm³	5 cm³	0·4253 grm.	0·0007 grm.
42.	0·5000 "	0·5 "	25 "	5 "	0·4257 "	0·0005 "
43.	0·1002 "	3·0 "	25 "	5 "	0·0844 "	0·0008 "
45.	0·0100 "	3·0 "	25 "	5 "	0·0077 "	0·0008 "

The experiments of Series G were made in exactly the same manner as those of Series F, except that varying amounts of magnesium chloride were present instead of the calcium salt. The results are uniform and exact, and indicate that barium may be separated from magnesium when the two are present in any proportion. It is probable that if magnesium chloride were present in an amount larger than 3 grm. in 30 cm^3 it would be necessary to make two treatments, as under those circumstances it shows a slight tendency to precipitate. The amount of mixed salts present should always, therefore, be kept below this limit.

Recapitulation.—Barium chloride is soluble to an extent not exceeding one part in 20,000 in pure concentrated hydrochloric acid, but the solubility increases very rapidly with the diminution in the strength of the acid. In concentrated hydrochloric acid containing ether it is soluble to an amount not exceeding one part in about 120,000. To utilize this fact for the separation of barium from calcium and magnesium the chlorides of the earths are dissolved in the least possible amount of boiling water and precipitated by 25 cm^3 of concentrated hydrochloric acid with the addition of 5 cm^3 of absolute ether after cooling. The acid should be added drop by drop at first allowing the precipitate formed to redissolve as long as possible, as the precipitate is thus obtained in a coarse crystalline condition and filters very quickly and is less liable to include foreign matter. After standing a few minutes the precipitate is to be filtered in a Gooch crucible, washed with hydrochloric acid containing about 10 per cent of ether and dried at 150°–200° C. The method is accurate and rapid, and possesses the further advantage when a number of determinations are to be made that the precipitate may be dissolved off of the felt by a little water and, after ignition, the crucible and felt may be used again without re-weighing. A felt upon which half a dozen precipitates were weighed did not change its weight to the extent of one-tenth of a milligram. The fumes of the strong acid cause no inconvenience if the filtration is performed in front of a good flue. A gas flame may be used in the flue without danger from the ether which seems to be firmly held by the hydrochloric acid. A flame was used to increase the draught in all of the experiments given and with entire safety, even when the filtrate contained 50 per cent by volume of ether.

The author wishes in concluding to acknowledge his indebtedness to Prof. Gooch for many helpful suggestions freely given in the course of the investigation.

ART. LXVI.—*Note on the Absorption of Radiant Heat by Alum;* by C. C. HUTCHINS, Bowdoin College.

IT seems to be the generally accepted opinion that a solution of alum acts as a particularly efficient absorber of rays of great wave length. It is certain that the alum cell is universally used and recommended wherever a transparent medium is desired for cutting off the so-called "dark" heat rays.

In the April number of this Journal Mr. F. J. Rogers states that the results of Julius Thomsen are in error because Thomsen used pure water instead of alum solution as an absorber.

Whence this idea in regard to the effect of alum solution arose it is difficult to say: I have searched in vain for any authority for it. Melloni's table, as far as it goes, shows that bodies in solution raise slightly the percentage of transmitted rays above that which passes through pure water.

I prepared a saturated solution of potash alum in distilled water and placed it in a cell $0{\cdot}6^{cm}$ thick. The sides of the cell were quartz plates $0{\cdot}15^{cm}$ thick. My heat-measuring apparatus was used to determine the transmission of the rays from a naked gas jet through this cell. The mean of ten galvanometer readings was 201 divisions.

The cell was then filled with pure water and the mean of ten readings found to be 196 divisions, showing, if anything, that water is a slightly better absorber than alum solution. When two hundred ohms resistance were added in the galvanometer circuit, the deflection produced by the unobstructed gas jet was 240 div. Through the water cell it was 21·5 div. and the per cent transmitted was 8·9. When a sheet of plate glass $0{\cdot}7^{cm}$ thick was interposed the deflection was 86 div. and the per cent transmitted was 35·8. Melloni shows that alum in its crystalline form cuts off all save nine per cent of the rays from a Locatelli lamp.

It is not easy to find perfect crystals of alum, but among a large number of ordinary crystals one was found from which a nearly flawless plate was cut. The plate was given a perfect polish on both sides by Brashear's method of working rock-salt surfaces. The plate was $0{\cdot}37^{cm}$ thick, and the deflection of the galvanometer by the gas jet through the plate was 23·4 div. and the per cent transmitted 9·7.

Hence it appears that a solution of alum is no better absorber than is water; and furthermore, that it would hardly pay to use plates of transparent alum, even if they were to be had.

Art. LXVII.—*Disruption of the Silver Haloid Molecule by Mechanical Force;* by M. Carey Lea.

[Read before the National Academy, April, 1892, by Dr. George F. Barker.]

In a paper published about a year ago on the subject of allotropic silver there was included an investigation into the action of the different forms of energy upon silver chloride and bromide.* It was there shown that these substances possessed an equilibrium so singularly balanced as to be affected by the slightest action of any form of energy. Such action produced a change which though it might be wholly invisible yet caused the breaking up of the haloid when subsequently placed in contact with a reducing agent. The forms of energy with which this effect was observed are:

1st. Heat.
2d. Light.
3d. Mechanical force.
4th. Electricity (high tension spark).
5th. Chemism.

It follows therefore that it is not light only that is capable of producing an invisible image *but that this power belongs alike to all forms of energy.* So that a slight impulse from any one of the forces just mentioned brings about a change in the equilibrium of such a nature that the molecule is more easily broken up by a reducing agent.

As respects four out of these five forms of energy, it was further shown that when made to act more strongly, they were able of themselves to disrupt the molecule without external aid. One form alone of energy, mechanical force, made an apparent exception to this general rule. The other four, when applied to a moderate extent, produced a latent image, applied more strongly they broke up the molecule.

The object of the present paper is to prove that this exception does not exist, and that as all forms of energy have been shown in the previous papers of this series to be capable of impressing an invisible image, so also with stronger manifestations, *any form of energy is capable of disrupting the molecule.*

I was able to show many years ago that mechanical force could produce a latent image. Lines drawn with a glass rod on a sensitive surface could be rendered visible by development in the same way as impressions of light. An embossed card pressed on a sensitive film left an invisible image which

*This Journal, April, 1891.

could be brought out by a reducing agent. The raised portions of the embossed work exerted a stronger pressure on the sensitive film than the rest of the card and these portions darkened when acted upon by a reducing agent. In the same way, the lines traced with a glass rod blackened under a developer. In each case, it was the portions which had been subjected to pressure which yielded first to the reducer. It was therefore clear that in the molecules which had received this slight pressure the affinities of the atoms had been loosened.

To bring these phenomena fully into line with the others it is now necessary to prove that an increased pressure can take the place of a reducing agent and disrupt the molecule. And this is actually the case.

It was found that the breaking up could be produced in two ways, by simple pressure, and by shearing stress. Silver chloride and bromide formed and washed in absence of active light were subjected to these agencies.

1. *Simple Pressure.*—In the first trial made with silver chloride, it was enclosed in asbestos paper which had been first ignited with a blast lamp to remove all traces of organic matter present. This method was tried in order that the chloride should be in contact with perfectly inactive material only, but it was not found to answer. The great pressure employed forced the dry chloride into the pores of the paper cementing it together, so that the opposite sides could not be separated. Platinum foil was then substituted with satisfactory results. With a pressure of about one hundred thousand pounds to the square inch, maintained for twenty-four hours, the chloride was completely blackened except at the edges, where owing to greater thinness the pressure was less. Very bright foil was used in order to detect the slightest discoloration that might occur, but none resulted; it was impossible to distinguish the portions which had been in contact with the darkened chloride from those that had not. The chloride did not assume the usual chocolate color, but changed to a deep, greenish black.

Silver bromide gave exactly the same results. It should be mentioned that the silver chloride and bromide were each precipitated with an excess of the corresponding acid.

As silver iodide precipitated with excess of potassium iodide is not darkened by light, it seemed improbable that it should be by pressure. The experiment was however tried and it was found that the iodide darkened fully to the same extent as the others This result surprised me so much that the experiment was repeated with every possible precaution. The result left no doubt that silver iodide, as well as the chloride and bromide is blackened by great pressure. All three silver haloids take on the same coloration, an intense greenish black. It was

found best to use the material air-dried. If at all moist the platinum foil bursts under the pressure and the experiment is invalidated. The air-dried salt retains a sufficient quantity of moisture.

2. *Shearing Stress.*—As a means of applying this form of force, the silver chloride precipitated with excess of hydrochloric acid and well washed, was put into a porcelain mortar and well triturated. The improbability that the small quantity of force that can be applied in this way would break up a stable molecule like that of silver chloride seemed so great, that at first, a substance tending to aid the reaction was added. Tannin was selected and when forcibly ground up with silver chloride the latter was soon darkened. Next a substance capable of taking up acid but having no reducing action was tried. Sodium carbonate was used. This also caused the chloride to darken. Finally it was determined to ascertain if the molecule of silver chloride could not be disrupted by stress alone. The chloride was placed in a chemically clean porcelain mortar and well triturated. For some time no effect was visible. After about ten minutes' action dark streaks began to appear and after five minutes' more work a considerable portion of the chloride was darkened. The end of the pestle was covered with a shining purple varnish. It had not become perceptibly warmer to the touch. On the violet purple substance nitric acid had no action, but aqua regia slowly whitened it. It was therefore what I have proposed to call silver photochloride, that is, a molecular combination of chloride and hemichloride. This experiment was carefully repeated with the same result. Silver bromide similarly treated gave a similar result. It was noticed that both chloride and bromide in darkening took on the familiar color between chocolate and purple, so generally seen in the darkening of these silver salts and differing strikingly from the greenish black color assumed by all three silver haloids under simple pressure.

The fact that the platinum foil remained absolutely unattacked when the silver haloid was reduced by simple pressure in actual contact with it, is interesting and would seem to show that in the reduction of the silver haloid the halogen is not at any time set free but that water, if present, is decomposed at the same moment with formation of halogen acid.

The observations recorded in this paper prove the existence of a perfect uniformity in the action of all kinds of energy on the silver haloids. The balance of the molecule is at once affected by the influence of any form of energy. A slight application produces an effect which, though invisible to the eye, is instantly made evident by the application of a reducing agent. The bonds which unite the atoms have evidently been in some

way loosened so that these molecules break up more easily than those to which energy has not been applied. Consequently, if the substance is submitted to the action of light, heat, or electricity, or if lines are drawn by a glass rod (shearing stress) or with sulphuric acid (chemism), a reducing agent blackens the parts so treated before it affects the parts not so treated. This justifies the statement made earlier in this paper that the phenomena of the latent image and of its development are not exclusively, or even especially connected with light, as hitherto supposed, but belong to all other forms of energy as well.

It is therefore true that every form of energy is not only capable of producing an invisible image, that is, of loosening the bonds which unite the atoms, but is also capable, if applied more strongly, of totally disrupting the molecule. This law, in a general form was proved in previous papers, with but a single exception, and that one exception is removed by the observations recorded in this paper.

As far as observation has gone silver compounds are the only ones that exhibit this universal sensitiveness. Of other substances, some are decomposed by heat, some by electricity or by chemical action and a few by light.

It has now been shown, as I believe for the first time, that mechanical force is competent without the aid of heat to break up a molecule that owes its existence to an exothermic reaction.

It is important to distinguish between the two treatments here described. In the case of shearing stress, force is expended in overcoming friction and in so doing produces heat. It may be questioned, however, whether the very small amount of heat thus generated has anything to do with the reaction. The heat is not perceptible, it is momentary, and it has been elsewhere shown that though moist silver chloride can be broken up by heat, the action is slow even at a temperature of 100° C.

In the case of simple pressure heat certainly plays no part. The material is small in quantity, is folded up in metal, is placed between large and heavy pieces of metal and the pressure is applied gradually by means of a screw. Even supposing a slight increase of temperature, it could not exceed one or two degrees and would be momentary. As just remarked, heat does not produce an effect except at about 100° C. and after many hours.

The powerful affinity which exists between silver and the halogens is well known. That this affinity can be counteracted and annulled by simple pressure—that the halogen can in part be forced out of the molecule by mechanical means unaided by heat, is remarkable.

It need scarcely be said that this phenomenon has nothing in common with decompositions produced by mechanical force in substances such as silver or mercury fulminate, nitrogen chloride and similar explosives. Such substances are all formed by endothermic reactions and their decompositions are exothermic. Heat does not need to be supplied, but only what Berthelot has named a "travail préliminaire," an impulse to start the reaction. But silver haloids are formed by exothermic reactions, consequently their decompositions are endothermic and require that the energy which was disengaged in their formation should be returned to effect their decomposition. The experiments described in this paper show that mechanical force may be made to supply this energy and so play the part of light, electricity or heat without previous conversion into any other form of energy.

The thermochemical reactions of the silver haloids have been studied by Berthelot and their reductions were found to be endothermic.* There can be no doubt therefore that an endothermic reaction can be brought about by simple pressure.

Philadelphia, April, 1892.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Polarization of Platinum by Oxygen and Hydrogen.*—A series of measurements has been made by Markofsky to ascertain the difference of potential developed between a plate of platinum entirely immersed in dilute sulphuric acid, freed from air by boiling, and a second plate partly immersed in this liquid and partly exposed to an atmosphere of pure hydrogen or pure oxygen gas. The experiments were varied by using an acid containing platinum sulphate, the strength of the solution being different in different experiments. Carbon electrodes were also employed in place of platinum. He finds that the potential-difference between a platinum plate in hydrogen and one in dilute acid free from gas, is 0·646 volt. If oxygen be substituted for the hydrogen, the polarization is reversed in direction and is equal to 0·372 volt. Moreover, this potential-difference remains the same whether the gases employed are produced electrolytically or by chemical processes. The author observed that the addition of platinum sulphate to the acid increases the potential-difference in

* Méchanique chimique, vol. ii, p. 411. The reduction of silver chloride to metal involves an absorption of Cal. 29·4. That to hemichloride has not been measured, but is, according to Berthelot, also endothermic. See also, Ditte, Les Métaux, I, pp. 232, 233.

the case of a hydrogen cell while this addition decreases it in the case of a cell containing oxygen. His results show the potential difference to be independent of the density of the gas and of its temperature up to 70°. With carbon electrodes, however, the phenomena obtained were quite different.—*Am. Phys. Chem.* II, xliv, 457; *J. Chem. Soc.*, lxii, 393, April, 1892. G. F. B.

2. *On the Basicity of Phosphoric Acid.*—D. BERTHELOT has studied the relative conductivities of the monobasic and dibasic phosphates and has shown that while the conductivity is the same for the monobasic ammonium and potassium phosphates, the conductivity of the dibasic ammonium salt is about six per cent less than that of the potassium salt. Moreover, in the case of the tribasic phosphates the conductivities are widely different, that of the potassium salt being much the greater. It is well known that when potassium, sodium or ammonium hydroxide is continuously added to a dilute solution of phosphoric acid, the decrease in the electrical conductivity of the solution is represented by a straight line up to the point at which one of the basicities of the acid is neutralized. So that, as it would appear, these three monobasic phosphates are not dissociated even in dilute solutions. At this point the conductivity-curve shows a well-marked angular deflection, and on continuing to add the base, the resulting increase in conductivity is again represented by a straight line up to the point corresponding to the formation of a dibasic phosphate. Consequently, these dibasic phosphates must also be stable even in dilute solutions. If more base be added, another change occurs in the direction of the curve, but now the change in conductivity is no longer represented by a straight line. Moreover there is no further change in direction at the point corresponding to the formation of tribasic phosphate. Hence the tribasic alkali phosphates are almost completely dissociated in dilute solutions. If the solution be made stronger, a distinct although small angular deflection may be observed at the point corresponding to the formation of tribasic phosphate. It would seem, therefore, that phosphoric acid differs materially from the true tribasic acids, such as citric, aconitic and tricarballylic, in the fact that in the case of these acids the monobasic and dibasic salts are partially dissociated in solution, while the tribasic salt is stable. Since according to Lenz the ammonium and potassium salts of strong acids show the same conductivity in dilute solution, while according to the author's experiments the conductivities of these two salts with feeble acids are distinctly different, though approximately the same, and the conductivities in the case of phenol are entirely different, he concludes that the first acid function of phosphoric acid is analogous to that of strong acids, the second to that of feeble acids and the third to that of phenols. In fact therefore phosphoric acid is not a true tribasic acid, but a monobasic acid with a complex function. Simular conclusions follow from thermochemical data.—*C. R.*, cxiii, 851, *J. Chem. Soc.*, lxii, 394, April, 1892. G. F. B.

3. *On the Occlusion of Hydrogen by Lead and other Metals.*—In order to explain certain physical phenomena of secondary battery action, NEWMANN and STREINTZ have examined the absorption of hydrogen by metals and especially lead. Two methods of charging the metal with the gas were employed: (1) charging electrolytically and (2) charging by passing the gas over or through the fused metal. Previous experimenters had used the former method; but since the plates were subsequently exposed to the air, the hydrogen was oxidized. The author therefore washed his plates in the absence of air with air-free water and dried them in pure carbon dioxide. But on igniting them only a trace of hydrogen was obtained. In using the second method, the metal was heated in pure hydrogen, the excess of hydrogen was expelled by means of nitrogen, and the metal was again heated in oxygen; whereby the occluded hydrogen was burned to water which was weighed. The following are the values obtained, the numbers representing the volumes of hydrogen absorbed by one volume of metal: Lead 0·15, 0·11; palladium 502·35 (at 450°); platinum sponge 29·95, 15·37, 12·13, 6·48; platinum black 49·30; gold 46·32, 37·31; silver 0·00; copper 4·81, 4·78; aluminum 2·72; iron 29·17, 9·38; nickel 16·85, 17·57; cobalt 153·00, 59·31. In the case of platinum sponge, of iron, of nickel and of cobalt, the successive values decrease with the same specimen of metal; the power of occluding the hydrogen diminishing with repeated use of the same sample.—*Monatsh. f. Chem.*, xii, 642; *Ber. Berl. Chem. Ges.*, xxv, (Ref.) 187, March, 1892. G. F. B.

4. *The Principles of Chemistry;* by D. MENDELÉEFF. Translated from the Russian (Fifth Edition), by George Kamensky. Edited by A. J. Greenaway. 2 vols. 8vo, pp. xvi, 611, vi, 487. London and New York, 1891. (Longmans, Green & Co.).—The first edition of this book, issued in 1870, marked an epoch in the history of chemistry, since in it was enunciated for the first time the periodic law of the elements, so inseparably connected with the name of its author. In reproducing the fifth edition in English, a great service has been done for chemical science among English-speaking people which cannot fail to produce a marked effect. The book itself is remarkable in many ways. In the first place, its treatment of the subject matter is profound and far-reaching. The author says: "The desire to direct those thirsting for truth to the pure source of the science of the forces acting throughout nature forms the first and most important aim of this book. The time has arrived when a knowledge of physics and chemistry forms as important a part of education as that of the classics did two centuries ago. In those days the nations which excelled in classical learning stood foremost just as now the most advanced are those which are superior in the knowledge of the natural sciences." The object of the book is "to acquaint the student not only with the methods of observation, the experimental facts and the laws of chemistry, but also

with the aspect of this science towards the invariable substance of varying matter." In it, "experimental and practical data occupy their place, but the philosophical principles of our science form the chief theme of the work." "In comparing the science of the past, the present and the future, in placing the particulars of its restricted experiments side by side with its aspirations for unbounded and infinite truth, and in restraining myself from yielding to a bias towards following the most attractive representation, I have endeavored to incite in the reader a spirit of inquiry, which, unsatisfied with speculative reasonings alone, should subject exery idea to experiment, excite the habit of stubborn work, necessitate a knowledge of the past, and a search for fresh threads to complete the bridge over the bottomless unknown." Such a standpoint as this is unique in chemical treatises. And an examination of the book shows these claims to have been fully met. Not only is the entire work based upon the law of periodicity, but a vein of what the author calls "scientific contemplation" runs through it, which "bears the stamp of creative power and comprehends the highest branch of scientific progress." In the second place, the book exhibits an exceptional fidelity to details, not only along the main line of the subject, but along collateral lines. Perhaps the most noticeable typographical feature in it, is its wealth of foot-notes, which occupy probably one-half of the entire text. These the author suggests, should be read only after the large text has been mastered. But so seductive are they and so valuable in their bearing upon the subject in hand, that no reader will be likely to postpone them to a second reading. Thus for example, the first foot-note considers in what the investigation of a substance or phenomenon of nature consists. And after enumerating seven points which go to make it up, the author says: "It is certain that it is only possible to thus study when we have taken as a basis some incontestible fact which is self-evident to our understanding; as for instance, number, time, space, movement, or mass. The determination of such primary or fundamental conceptions (categories) although not excluded from the possibility of investigation, frequently does not subject itself to our present mode of scientific generalization. Hence it follows in the investigation of anything there always remains something which is recognized without investigation or admitted as a known factor." Evidently, therefore, while Mendeléeff's book may not be the best one for a beginner to essay, it is decidedly the most desirable one for the chemical student to read at some stage of his scientific education. The knowledge which it contains is indispensable in a course of thorough chemical training.

The translation, in the main, has been faithfully performed, in spite of the difficulties inherent to such a task. We regret, however, that the original wood-cuts have not been reproduced in the English edition. The thanks of English and American chemical students are due the publishers for placing in their hands and their

own language the most philosophical work on chemistry which the nineteenth century has yet produced. G. F. B.

5. *Manual of Chemical Technology, by Rudolf von Wagner*, translated and edited by WILLIAM CROOKES, F.R.S., from the thirteenth enlarged German edition as remodelled by Dr. FERDINAND FISCHER. 968 pp. large 8vo, with 596 illustrations. New York, 1892, (D. Appleton and Co.).—Wagner's Chemical Technology has so long been a standard work of reference, both in the original form and in the English translation, that it hardly seems to call for new commendation. The present edition, however, is substantially a new work and has many excellent features of matter and arrangement due to the present editors. The last edition prepared by Wagner himself was the eleventh, published shortly before his death in 1880. In the latest (13th) German issue, a new and more logical arrangement of the subject-matter has been adopted, many new subjects have been introduced and others have been thoroughly revised. Thus it is stated that, as compared with the eleventh edition, more than half the text and illustrations are new. The former English edition appeared twenty years ago; the present one is based upon the 13th German edition, and the English editor has made various minor modifications, and added many explanatory notes, bibliographical references, etc., to adapt it to home conditions.

The book is rich in valuable information in every branch of chemical technology and is indispensable to all interested in this field.

6. *Laboratory of Chemistry*, by J. E. ARMSTRONG and J. H. NORTON. 144 pp. 8vo. New York (American Book Company).—This is a useful little book detailing 164 experiments to be performed by the student in the laboratory. The experiments are well selected and described with sufficient fulness; with the aid of a competent teacher they should give good results.

7. *Untersuchungen über die Ausbreitung der elektrischen Kraft von* Dr. HEINRICH HERTZ. 294 pp. 8vo, Leipzig, 1892. (Johann Ambrosius Barth.)—It would be difficult to find, in the recent literature of the subject of Physics, contributions more distinctly "epoch-making" than those of Hertz, carried on through the last five years, on the production and propagation of electrical waves. These papers discuss, in a word, the production of electrical waves by the oscillatory electric discharge, as of an induction coil; their propagation through the ether; reflection from metallic surfaces; refraction through non-conductors; interference, polarization, and in fact all the phenomena characteristic of light waves, to which indeed they correspond although relatively of enormous length. By them Maxwell's theory in regard to the mutual connection between electrical and light phenomena has received the most signal confirmation, and new directions for experiment and theory have been opened out in which other workers also have gained, and are gaining, important results. The original papers have been for the most part published in Wiedemann's

Annalen and are hence not inaccessible, at the same time the subject is one of such unique interest that their republication in a single volume is a service on the part of the publishers for which all physicists will be grateful. Moreover, this has given the author an opportunity to present a general summary of the subject from the present standpoint with the correction of some errors, and this gives unity and completeness to the whole subject.

8. *Vorlesungen über Maxwell's Theorie der Elektricität und des Lichtes von* Dr. LUDWIG BOLTZMANN. I Theil, Ableitung der Grundgleichungen für ruhende, homogene, isotrope Körper. 139 pp. 8vo. Leipzig, 1891.—This volume is a highly valuable contribution to the subject of Maxwell's theory. Starting from Helmholtz's theory of cyclical movements, the author has developed the theory of electrical oscillations in circuits with condensers; then the general equations of electrical movement in stationary homogeneous and isotropic conductors and semiconductors, with applications to the fundamental problems of electrodynamics, induction, electrostatics and the theory of light. The author intends to follow this contribution by other parts in which he will give the application to anistropic bodies and those in motion, the theory of dispersion, double refraction, the rotation of the plane of polarization and finally the oscillations discovered by Hertz.

II. GEOLOGY AND NATURAL HISTORY.

1. *A Summary Description of the Geology of Pennsylvania*, in three volumes, with a new Geological Map of the State, a map and list of Bituminous Mines and other illustrations; by J. P. LESLEY, State Geologist. Vol. I, 719 pp. 8vo. Harrisburg, Pa.—The long series of Annual Reports of the Second Geological Survey of Pennsylvania, under Prof. Lesley as Director, yield in value to none from the other State surveys. They do not comprise a full account of the animal paleontology of the State and some points are left doubtful on this account. But in other respects the geology has been well studied and described by an able corps of geologists; and, in view of the position of the area with reference to the Appalachians, and its comprising the whole Paleozoic series, the final Summary Report should be a work of great interest. The first of the three volumes of the final Report, has been recently issued. It treats of the Laurentian, Huronian, Cambrian and Lower Silurian formations. It opens with extended remarks c.. the nature and uncertainties of geological knowledge and reasoning. The discussion of the various views of the investigators of the Archæan and Cambrian formations occupy the next 120 pages. In the remaining part of the volume, treating of the overlying formations, and their stratigraphical relations, many sections and maps illustrate finely the flexures and positions of the rocks, and several pages of plates, made up of figures of fossils from various sources, are intro-

duced to afford information on the life of the several periods. Further, Prof. Lesley has given the volume a practical value by devoting many of its pages to the mines and ores of iron connected with the Lower Silurian and older rocks, to the limestone and slate quarries, and to unsuccessful searchings in these inferior formations for mineral oil and gas.

2. *Fossil Botany; being an Introduction to Palæophytology from the Standpoint of the Botanist.* By H. GRAF ZU SOLMS-LAUBACH. Authorized English translation, by HENRY E. F. GARNSEY; revised by ISAAC BAYLEY BALFOUR. Oxford, 1891. 401 pp., 49 illustrations.—Owing to the fact that by far the greater part of the material considered by Count Solms in the present work is Paleozoic, the remainder being taken almost exclusively from the Older Mesozoic, the student of recent plants is neither conducted back along the chain of vegetable life in geological time from present types to their remote ancestors, nor may he, after discussing the generally somewhat problematic Paleozoic plants, proceed to view, by the light of ample illustrations, the development or gradual succession of plant life up to the recent forms. The entire Angiospermic era in the history is wanting, and relatively little is given to show the connection of the fossils discussed with the living forms. The paucity of figures, without systematic descriptions, as well as its biological character, render the work of but minor value to the geologist. Its great use will be to the paleontologist; not as a handbook or manual—it is too abridged and we have other good handbooks nearly contemporaneous with the German edition—but as embodying the views of a justly distinguished structural botanist, reasoning from the botanical standpoint, in a field of troubles wherein the every-day workers are too often unfamiliar with the morphology and histology of recent plants. To the paleobotanist the work is indispensable if for nothing more than the author's opinions and conclusions which are expressed with fairness and conservatism. Its value is further increased by his criticism and verification of many originals of other workers as well as by many previously unpublished observations made from new material.

It is unfortunate that, however much a review from time to time of the existing knowledge of fossil floras may be needed, the same rapidity of progress in paleobotany which makes a résumé so necessary at a given time soon leaves that résumé, with the writer's opinions, among the historical literature of the science. There are but few fields in which discoveries more strongly affecting the ideas of ancient organic life have been made within a few years, and perhaps no science in which classificatory delimitations have shifted about more, than in Paleozoic phytology. It is, therefore, not a little disappointing to find in this authorized translation, dated four years after the German edition, no mention made of the wealth of valuable researches, some of them fundamentally modifying our ideas of the develop-

ment of certain types, recorded during the intervening four years. Surely a few of the most important of these works, such as Williamson's recent memoirs on the Organization of the Carboniferous plants, in which, among other things, the secondary growth in some Paleozoic fern stems is demonstrated, Zeiller's classical monographs on the Valenciennes and Autun floras, Renault and Zeiller's Commentry flora, Dawson's Geological History of Plants, with new additions to our knowledge of the pre-Carboniferous floras, Stur's detailed examination of the Schatzlar Calamariæ, Kidston's studies among the British collections, Weiss's Sigillariæ, and possibly Grand 'Eury's flora of the Gard basin, with its correlative and synthetic discoveries, should have been given at least foot-note mention or comment.

It would have given much satisfaction to American readers, if Count Solms had included in his consideration the very interesting, and in some respects unique types described from the Lower Carboniferous of Ohio by Newberry in 1873 and Andrews in 1875, both of whose reports, published in the Ohio Paleontology, are not even mentioned. But though unrevised, and virtually unillustrated, Solms-Laubach's will for a long time be an invaluable reference work for vegetable paleontologists; and while many will wish that the systematic names were distinguished in some way in the print of the Oxford edition, most of us are obliged for the translation. D. W.

3. *Ueber einige carbone Pflanzenreste aus der Argentinischen Republik;* von Dr. LADISLAUS SZAJNOCHA. Sitzb. k. Akad. Wiss., Wien, Math.-Nat. Cl., vol. c, Abth. 1, 1891, pp. 199–209 [1–11], Pl. I, II.—The results, which Dr. Szajnocha presents in this preliminary publication, of the examination of a few specimens of fossil plants from the Argentine Republic are of great interest from the fact that they offer the first satisfactory proof of the existence of the Carboniferous system in that great territory. Six species were found whose identities and affinities show that the horizon is in the Carboniferous system, and most probably in the Sub-carboniferous. Two, perhaps three, of the species are found in the United States. The approximate locality, Retamito, Prov. San Juan, is in about 32° S. lat., near the provincial border on the railroad from San Juan to Mendoza. The previously known South American Carboniferous plant-bearing localities, the material from which was studied by Carruthers, are in the provinces of S. Catharina and Rio Grande do Sul, Brazil, and belong to horizons probably much higher than that now recognized in the Argentine.

4. *Cambrian of Sardinia.*—A paper on the Cambrian slates of Sardinia by J. G. BORNEMANN is contained in the 56th volume of the Nova Acta Academiæ L.-Car. Germ. Naturæ Curiosorum, Halle, 1891. It is illustrated by 10 plates and describes a number of new species of Trilobites and other species. Four new genera of Trilobites are introduced: *Olenopsis* (*O. Bornemanni* being *Olenus Zoppii*, var. *elongata*, of Meneghini), *Meta-*

doxides (*M. torosus*=*Paradoxides torosus* of Meneghini), *Meneghinella*, and *Giordanella* (*Illœnus Menghini* of Bornemann, 1883). The beds afford also two new species of *Archæocyathus* and a related species called *Dictyocyathus tenerrimus;* also among Gasteropods, a *Capulus* (?) a *Carinaropsis* (?) and a *Bellerophon* (?), also a *Confervites.*

5. *Fossils in the St. Peter's Sandstone.*—The sandstone in the railroad cuts about five miles south of St. Paul, Minnesota, has afforded Mr. F. W. SANDESON fossils of the species *Murchisonia gracilis*, and probably *M. tricarinata*, a probable *Maclurea*, *Cypricardites rectirostris* Hall, and two other species of the genus, and a doubtful *Modiolopsis.* They resemble species found in the lower part of the Trenton shales and in the Trenton limestone overlying the St. Peter's sandstone.—*Bull. Minn. Acad. Nat. Sci.*, iii, 318.

6. *Correlation Papers: The Eocene of the United States*, by WM. B. CLARK, Bull. 83, U. S. Geol. Survey. This makes the *fourth* of the valuable series of Correlation papers published by the U. S. Geological Survey.

7. *Glacier Rock-crushing.*—Mr. W. G. TIGHT has described, and illustrated by fine phototypes various examples of the crushing of the surface rocks near Newark, in Licking Co., Ohio, in the Bulletin of the Scientific Laboratories of Denison University, vol. vi, p. 12.

8. *The System of Mineralogy of James D. Dana*, 1837–1868: *Descriptive Mineralogy.* Sixth edition by EDWARD S. DANA.—Entirely rewritten and much enlarged, illustrated with over 1400 figures, pp. i–lxii, 1134, large 8vo. New York, 1892, (John Wiley and Sons.)—Twenty-four years have passed since the fifth edition of this work was published, and the rapid progress of the science during that time, as also the development of the plan of the work, have made the rewriting of nearly the whole necessary, with an addition of about one-half to the size. In general, the excellent and well tried plan of the former edition has been retained, especially as regards the historical lists of synonyms, the system of classification, and the concise and compact arrangement and style of description. Changes, however, of more or less importance are made at many points, and in certain directions the work has been done over again from the foundation.

Some details in regard to the work are here condensed from the Preface. On the crystallographic side it has been the attempt to trace back to the original observer the fundamental angles for each species, then the axes have been recalculated from them, and finally the important angles for all common forms have been calculated (anew, in every case), from these axes. The lists of forms have been made up as completely as possible from the original authorities, with the symbols on both the systems of Miller and Naumann, though the preference is given to the former. References to the authors are given freely; and these, with the others relating to the history of the names, and further those in connection with the lists of

analyses, present a fairly complete literature, in compact form, for each species. Where, in the case of common species, the literature is very voluminous and has been carefully worked up by some author, this source of minuter detail is also indicated. Of the figures, about 1400 in number, all but very few of those in the body of the work have been made anew and a large part, particularly those illustrating American species, have been drawn from original data. The habits of the crystals, methods of twinning, and the physical characters, especially those on the optical side, have been carefully rewritten and in general are given with much fulness. In the lists of analyses, the plan has been to give all that are useful for a complete understanding of the composition of each species. This means all reliable analyses in the case of the rare species or those of complex composition, but in the case of some common species only the most important and typical are selected; also where the old analyses have been largely superseded, in consequence of the more accurate results of new chemical methods, reference is made for them to the former edition. In this and in other directions the preceding edition must still retain its importance in the history of the science.

9. *On the supposed occurrence of Platinum in North Carolina.*—Prof. F. P. Venable has made a critical examination of the evidence upon which the often repeated statements rest, that platinum has been found in North Carolina. The conclusion reached is that this evidence (based chiefly upon the report of Shepard) has very slight value. Recent careful attempts to find platinum in the gold washings have failed. The only definite account of its occurrence is that of Clingman, reported by Shepard, which is far from being conclusive.—*Journ. Elisha Mitchell Sci. Soc.*, vol. viii, Pt. II.

10. *A Summary of Progress in Mineralogy and Petrography in* 1891, by W. S. Bayley.—Professor Bayley's notes reprinted from the pages of the monthly issues of the "American Naturalist" give a useful record of the year's work in Mineralogy and Petrography.

11. *Gay-lussite from San Bernardino Co., California.*—An account is given by H. G. Hanks in the *Mining and Scientific Press* of March 26, of a peculiar variety of Gay-lussite from the borax fields of San Bernardino Co., California. It forms a confused semi-crystalline mass without well defined crystals. It is interesting as representing the variety from which, in the opinion of the author, the thinolite of Lake Lahontan and Mono Lake has been formed.

III. Miscellaneous Scientific Intelligence.

1. *Report of the Smithsonian Institution for* 1890.—The Smithsonian Institution, whose multifarious work for the advancement of science is of the very highest importance to the country, has recently issued its Annual Report for 1890, and the Report of the U. S. National Museum for 1889. The value of

the Annual Report is increased, as usual, by the republication of various recent scientific papers of difficult access to most interested readers besides Reports of Progress in some departments. The latter include Reports on the Progress of Astronomy for 1889, '90, by W. C. WINLOCK, and on the Progress of Anthropology by O. T. MASON: also papers On the Age of Bronze in Egypt by O. MONTÉLIUS; the prehistoric races of Italy by Canon I. TAYLOR; On the Antiquity of Man by JOHN EVANS; On Temperature and life by H. DE VARIGNY; the researches of Dr. R. KŒNIG on the physical Basis of Musical Harmony by Prof. S. P. THOMPSON; On the Physical Structure of the Earth by H. HENNESSY; On Color-vision and Color-blindness by R. B. CARTER, and others. The Report of the National Museum contains, besides many other papers, a full account by WM. J. THOMPSON of the U. S. Navy, of Easter Island, its people, geology, antiquities, and hieroglyphic tablets with their interpretation, illustrated by many fine plates and occupying over 100 pages; a paper on Aboriginal Skin-dressing, with many illustrations, by O. T. MASON; on Animals recently extinct or threatened with extermination by F. A. LUCAS, with many plates, among these a colored plate (facing p. 647) of the "Tile Fish," the most remarkable case of extinction on record, reported upon by Prof. Verrill in 1882 in this Journal, xxiv, 366, and in 1884 by J. W. Collins in the Report of the Commissioner of Fish and Fisheries for 1882, Washington, 1884.*

The volume closes with a list of the publications of the Museum during the year ending with June 30, 1889.

2. *Boston Society of Natural History.*—A Grand Honorary Prize, placed at the disposal of the Boston Society of Natural History by the late Dr. William J. Walker "for such investigations or discovery as may seem to deserve it, provided such investigation or discovery shall have been made known or published in the United States at least one year previous to the time of award," has been unanimously awarded to Professor James D. Dana. This prize, of the maximum sum of one thousand dollars, is given "in recognition of the value of the scientific work of Professor Dana and in testimony of the Society's high appreciation of his services to science."

For the annual Walker Prizes, a first prize of one hundred dollars has been awarded to Baron Gerard de Geer, of Stockholm, for an essay entitled "On Pleistocene changes of level in eastern North America," and a second prize of fifty dollars to Prof. William M. Davis of Cambridge, for an essay on "The subglacial origin of certain eskers."

3. *Proceedings of the Colorado Scientific Society*, vol. iii, Pt. 3, 1890.—This concluding part of the third volume published by the Colorado Scientific Society contains a number of valuable

* Prof. Verrill, in a paper in 1881 (this Journal, xxii, 295) states that a single "trawl line" in the summer of 1880 brought up 73 of these fishes, weighing 541 pounds, and varying in weight from 2½ to 31 pounds. The color which he gives is "brownish gray, more or less covered with bright yellow spots."

papers, including: On the Geology of the Rosita Hills by W. Cross; on the nature of the chemical elements by C. S. Palmer; on the columbite and tantalite of the Black Hills by W. P. Headden and others. The address of the retiring President, R. C. Hills, on the orographic and structural features of the Rocky Mountain Geology, a paper of much interest, fills the last one-hundred pages.

4. *Volcano of Kilauea, Hawaii.*—Reports from Kilauea in the Hawaiian Gazette of Feb. 23, state that the great basin of Halemaumau in the southern part of the crater of Kilauea, contains a lake of lava 1300 feet in diameter, almost the whole surface of which is in constant action.

5. *Physiography:* a class book for the Elementary Stage of the Science and Art Department by J. Spencer, B.Sc., F.C.S. 229 pp. London, 1891 (Percival and Co.).—The many subjects embraced under the head of Physiography are treated in this little book clearly and simply but, of necessity, with great brevity.

6. *A universal English-German and German-English Dictionary* by Dr. Felix Flügel. Fourth entirely remodelled edition of Dr. J. G. Flügel's Complete Dictionary of the English and German Languages. Braunschweig, 1890–1892. (George Westermann.)—This great work is now completed in three large volumes, of which the English-German part forms the first two and the German-English part the third. It has been a most laborious undertaking carried through with untiring scholarly effort and the final result is most satisfactory and reflects great honor upon the author.

7. *The Ward Collection of Meteorites.* 74 pp. 8vo. Rochester, N. Y.—This catalogue gives a descriptive price list of the meteorites in the large collection of Ward's Natural Science Establishment at Rochester; casts of a number of specimens are also included. Detailed descriptions with illustrations are given of a number of the meteorites, as La bella Roca, the Rockwood, Hamilton Co., Texas, Puquois, Chili, Washington Co., Kansas, and others.

Cyclone Memoirs, Part IV, Arabian Sea, pp. 301-424, large 8vo. An inquiry into the Nature and Course of Storms in the Arabian Sea, and a Catalogue and brief history of all recorded Cyclones in that sea from 1648 to 1889, by W. L. Dallas, Esq. Published by the Meteorolog. Dept. of the Government of India, under the direction of J. Eliot, M.A., Met. Reporter to the Gov. of India. Calcutta, 1891.

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APPENDIX.

ART. XLVIII.—*Notes on Triassic Dinosauria;* by O. C. MARSH. (With Plates XV, XVI, and XVII.)

THE presence of Dinosaurs in the Trias is indicated by many footprints, and various bones, nearly all of which are fragmentary. The footprints were long supposed to be those of birds, while the osseous remains were most of them not sufficiently characteristic to admit of determination. Three or four specimens in this country, however, and as many more in Europe, each with characteristic parts of the skeleton, have been known for some time. These prove the Dinosaurian nature of the animals beyond question, but throw little light upon their exact affinities. Recently, the writer has obtained from the Connecticut River sandstone the greater part of three skeletons of small Dinosaurs, all of much interest. Some portions of these have already been described,* and, in the present paper, additional remains are figured, and with them a few nearly allied fossils from European localities. The Triassic *Dinosauria* as a whole will be discussed by the writer in a later communication.

Anchisaurus colurus.

The type specimen of this species, one of the most perfect Dinosaurs ever discovered, has now been worked out of the hard matrix in which it was imbedded, and the skull and limbs are represented in the accompanying plates.

The skull was somewhat crushed and distorted, but its main features are preserved, and its more important characters can be determined with certainty. In Plate XV, figure 1, a side view is given, one-half natural size. One prominent feature shown in this view is the bird-like character of the skull. The nasal aperture (*a*) is small, and well forward. There is a large antorbital opening (*b*), and a very large orbit (*o*). This is elongated oval in outline. It is bounded in front by the prefrontal, above by the same bone, and a small extent of the frontal, and further back by the postfrontal. The postorbital completes the orbit behind, and the jugal, below. The supratemporal fossa (*d*) is large, and somewhat triangular in outline. The infratemporal fossa is quite large, and is bounded below by a slender quadratojugal. The quadrate (*q*) is much inclined forward. The teeth are remarkable for the great number in

* This Journal, vol. xxxvii, p. 331, April, 1889; and vol. xlii, p. 267, September, 1891.

use at one time. Those of the upper jaw are inclined forward, while those below are nearly vertical. The lower jaw has the same general features of this part in the *Theropoda*.

In Plate XVI, figures 1 and 2, the same skull is shown, also one-half natural size. The top of the skull, represented in figure 1, is considerably broken, and this has made it difficult to trace the sutures, but the general form and proportions of the upper surface are fairly represented. In figure 2, only the back portion of the cranium is shown. The foramen magnum is remarkably large, and the occipital condyle is small and oblique. The basipterygoid processes are unusually short.

The neck vertebræ are long and slender, and very hollow. Their articular ends appear to be all plane or slightly concave. The trunk vertebræ are more robust, but their centra are quite long. The sacrals appear to be three in number.

The scapular arch is well preserved. The scapula, shown in Plate XV, figure 2, *s*, is very long, with its upper end obliquely truncated. The coracoid (*c*) is unusually small, and imperforate. The sternum was of cartilage, some of which is preserved. The humerus (*h*) is of the same length as the scapula, and its shaft is very hollow. The radius and ulna are also both hollow, and nearly equal in size.

There is but one carpal bone ossified in this specimen, and this is below the ulna. There were five digits in the manus, but only three of functional importance, the first, second, and third, all armed with sharp claws. The fifth (V) was quite rudimentary. The fore foot of the type species of *Anchisaurus* is shown one-half natural size, on Plate XVI, figure 3.

The pelvic bones are shown in figure 3 of Plate XV. The ilium (*il*) is small, with a slender preacetabular process. The ischia (*is*) are elongated, and their distal ends slender, and not expanded at the extremity. The pubes (*p*) are also long, imperforate, and not coössified with each other. The anterior part is a plate of moderate width. The ischia of the type species of this genus are shown on Plate XVII, figure 6.

The femur (*f*) is much curved, and longer than the tibia (*t*). The latter is nearly straight, with a narrow shaft. The fibula (*f'*) when in position was not close to the tibia, but curved outward from it. All these bones have very thin walls. The astragalus (*a*) is small, closely applied to the tibia, and has no ascending process. The calcaneum (*c*) is of moderate size, and free. There are only two tarsal bones in the second row.

The hind foot had four functional digits, all provided with claws. The fifth was represented only by a rudiment of the metatarsal (V). The first digit was so much shorter than the second, third, and fourth, that this foot would have made a three-toed track very much like the supposed Bird-tracks of the Connecticut River sandstone.

On Plate XVI, figure 4, is shown the hind foot, also one-fourth natural size, of *Ammosaurus*, a genus nearly allied to *Anchisaurus*. In this foot, the tarsus is much more complete. The astragalus has a slight ascending process, the calcaneum is closely applied to the end of the fibula, and there are three well-developed bones in the second row. The fifth digit had only a single phalanx. The sacrum and ilia of the type species of *Ammosaurus* are shown on Plate XVII, figure 3.

Anchisaurus solus, sp. nov.

A fortunate discovery has recently brought to light almost the entire skeleton of a diminutive Dinosaur, which may be referred to *Anchisaurus*, but clearly belongs to a distinct species. It was found in nearly the same horizon as the remains above described, and in the immediate vicinity, so there can be little doubt that it was a contemporary. The skeleton is imbedded in a very coarse matrix, so difficult to remove that the investigation is only in part completed. The portions uncovered show the animal to have been about three feet in length, and of very delicate proportions. The bones of the skeleton are almost all extremely light and hollow, but most of them are in fair preservation.

The skull, so far as it can now be observed, resembles the one just described. The teeth are numerous, and inclined forward. The orbit is very large. The quadrate is inclined forward, and the lower jaw is robust. The entire skull is about 65^{mm} in length, and the lower jaws the same.

The neck was very long and slender, the first five cervicals measuring 80^{mm} in extent. The dorsals are also elongated, the last six covering a space of 135^{mm}. The number of vertebræ in the sacrum cannot yet be determined. The caudal vertebræ are short, the first ten occupying a space of 140^{mm}.

The humerus has a very large radial crest, and is 66^{mm} in length. The rest of the fore limb, so far as made out, is similar to those in the species described. The tibia is about 88^{mm} in length. There were five digits in the hind foot, but the fifth is represented only by the rudimentary metatarsal. The animal when alive was about as large as a small fox.

The European Triassic Dinosaurs with which the above American forms may be compared are mainly represented by the two genera *Thecodontosaurus*, Riley and Stutchbury, from the upper Trias, or Rhætic, near Bristol, in England, and *Plateosaurus* (*Zanclodon*), von Meyer, from nearly the same horizon, in Germany. The writer has investigated with some care the type specimens, and nearly all the other known remains of these genera found at these localities.

The remains of *Thecodontosaurus* are of special interest for comparison, and a portion of the skull is given on Plate XVII, figures 1 and 2, and the fore leg on Plate XVI, figure 5. For these remains, the writer is indebted to the trustees of the Bristol museum. The base of the skull shown on Plate XVII differs in several important respects from that of *Anchisaurus*, particularly in its extended parasphenoid, and the very long basipterygoid processes. The fore leg as a whole, especially the fore foot, is much like that of *Anchisaurus*, but in the latter, the coracoid is very small, and without a foramen. In *Thecodontosaurus*, it is much larger, has a foramen, and is coössified with the scapula.

Plateosaurus (*Zanclodon*) includes reptilian forms much larger than those described above. The pubis and ischia both serve to distinguish this genus from the American and British forms. The ischia have their distal ends expanded, as seen in Plate XVII, while the pubes are broad, imperforate plates.

The further discussion of these remains and of the other Dinosaurs from the Triassic will be given elsewhere.

New Haven, Conn., May 24, 1892.

Explanation of Plates.

Plate XV.

Figure 1.—Skull of *Anchisaurus colurus*, Marsh; side view. One-half natural size. *a*, nasal opening; *b*, autorbital opening; *bp*, basipterygoid process; *c*, lower temporal fossa; *d*, upper temporal fossa; *f*, frontal; *j*, jugal; *n*, nasal; *o*, orbit; *oc*, occipital condyle; *p*, parietal; *p'*, paroccipital process; *pf*, prefrontal; *pm*, premaxillary; *ps*, parasphenoid; *q*, quadrate; *so*, supraoccipital.

Figure 2.—Bones of left fore leg of same individual; outside view. *c*, coracoid; *h*, humerus; *r*, radius; *s*, scapula; *u*, ulna; I, first digit; V, fifth digit.

Figure 3.—Bones of left hind leg of same individual; outside view. Both figures are one-fourth natural size. *a*, astragalus; *c*, calcaneum; *f*, femur; *f'*, fibula; *il*, ilium; *is*, ischium; *p*, pubis; *t*, tibia.

Plate XVI.

Figure 1.—Skull of *Anchisaurus colurus*; top view.

Figure 2.—Base of same skull; back view. Both figures one-half natural size.

Figure 3.—Left fore foot of *Anchisaurus polyzelus*, Hitchcock, sp.; back view. One-half natural size. *c*, central; *r*, radial; R, radius; U, ulna.

Figure 4.—Right hind foot of *Ammosaurus major*, Marsh; front view. One-fourth natural size. F, fibula; T, tibia; *t2*, *t3*, *t4*, tarsal bones.

Figure 5.—Bones of left fore leg of *Thecodontosaurus platyodon*, Riley and Stutchbury; outside view. One-fourth natural size.

Plate XVII.

Figure 1.—Base of skull of *Thecodontosaurus platyodon*; seen from the left.

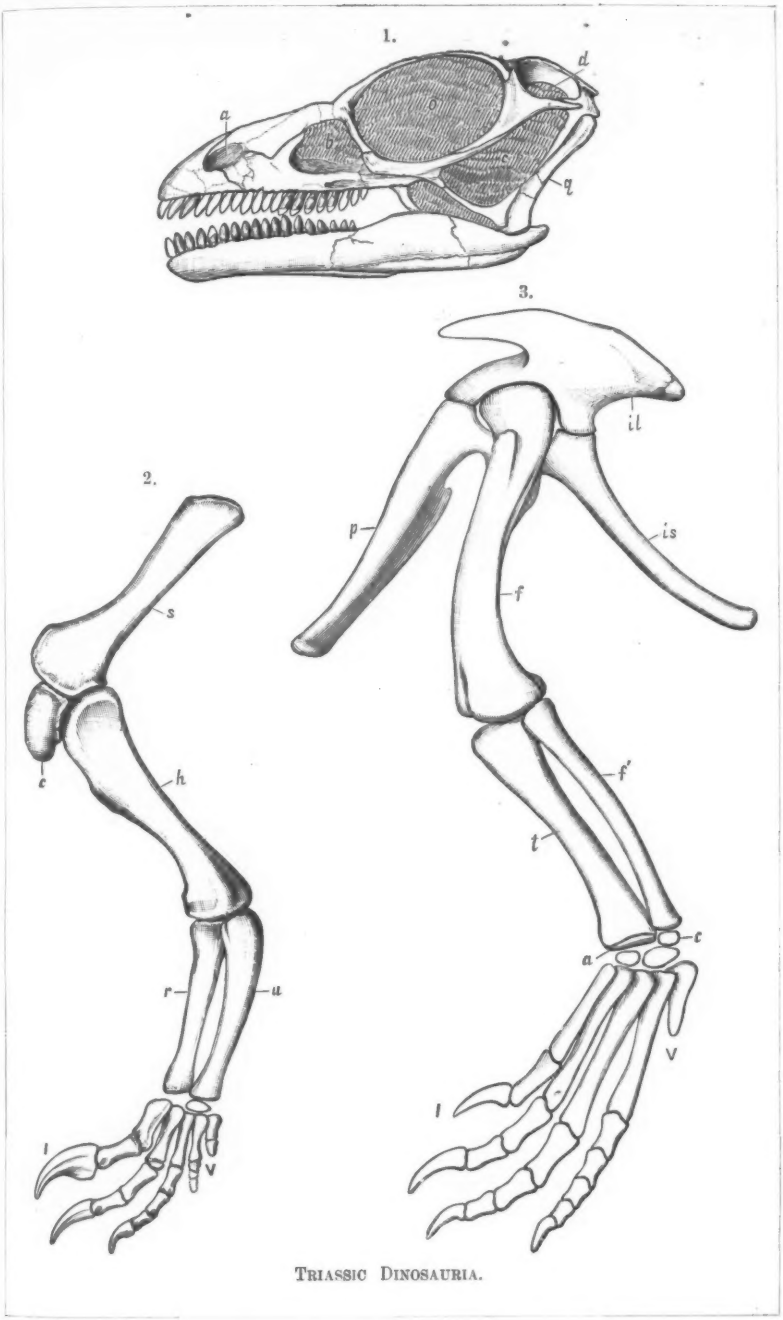
Figure 2.—The same specimen; back view. Both figures are one-half natural size.

Figure 3.—Sacrum and ilia of *Ammosaurus major*; seen from below. One-fourth natural size. *ac*, acetabulum; *is*, face for ischium; *pb*, face for pubis; *1*, *2*, *3*, sacral vertebræ.

Figure 4.—Pubis of *Plateosaurus* (*Zanclodon*) *suevicus*, von Meyer. One-sixth natural size. *a*, front view; *b*, back view; *s*, symphysis.

Figure 5.—Distal ends of ischia of same. One-sixth natural size. *p*, posterior.

Figure 6.—Ischia of *Anchisaurus polyzelus*; seen from above. One-half natural size. *a*, distal ends; *il*, face for ilium; *pb*, face for pubis.



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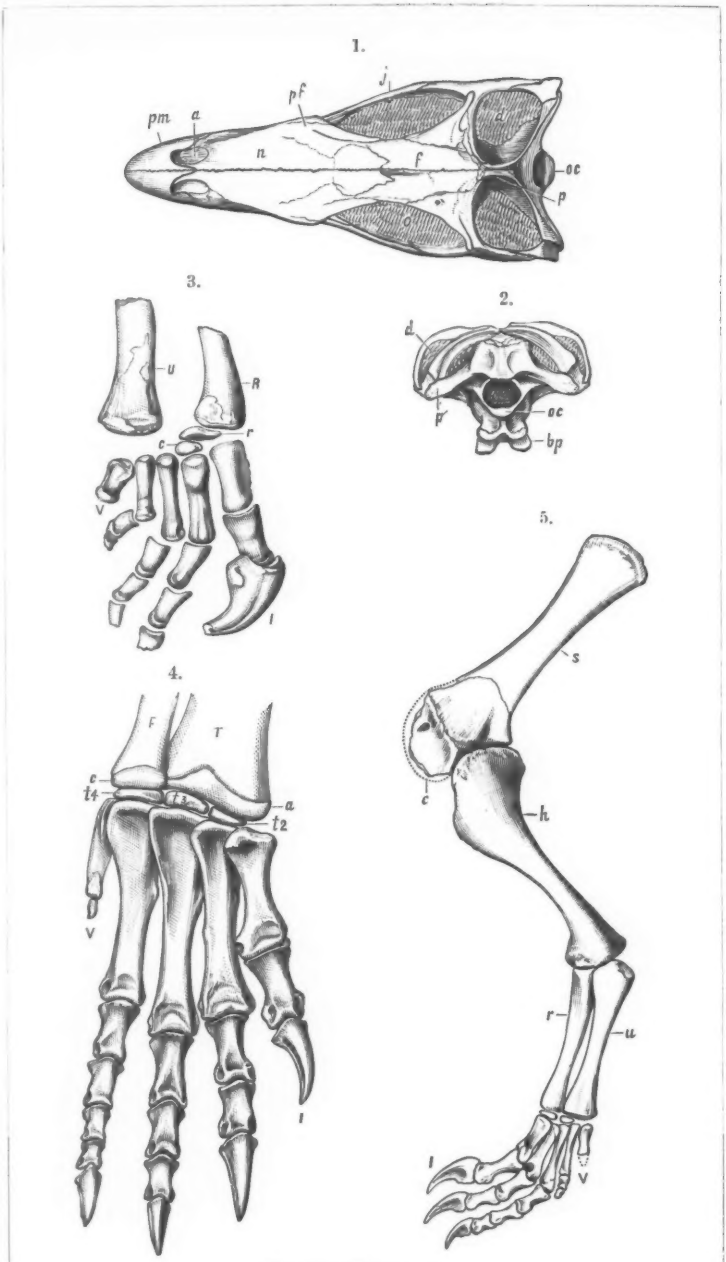

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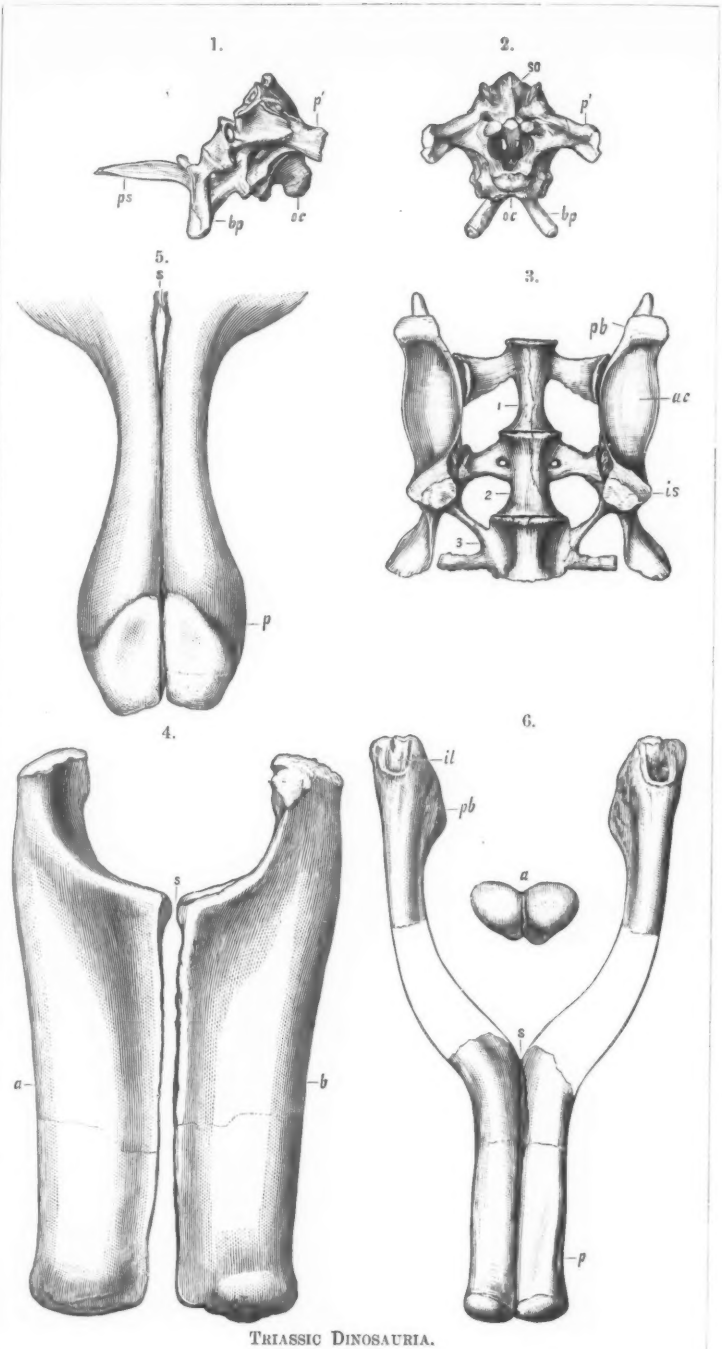

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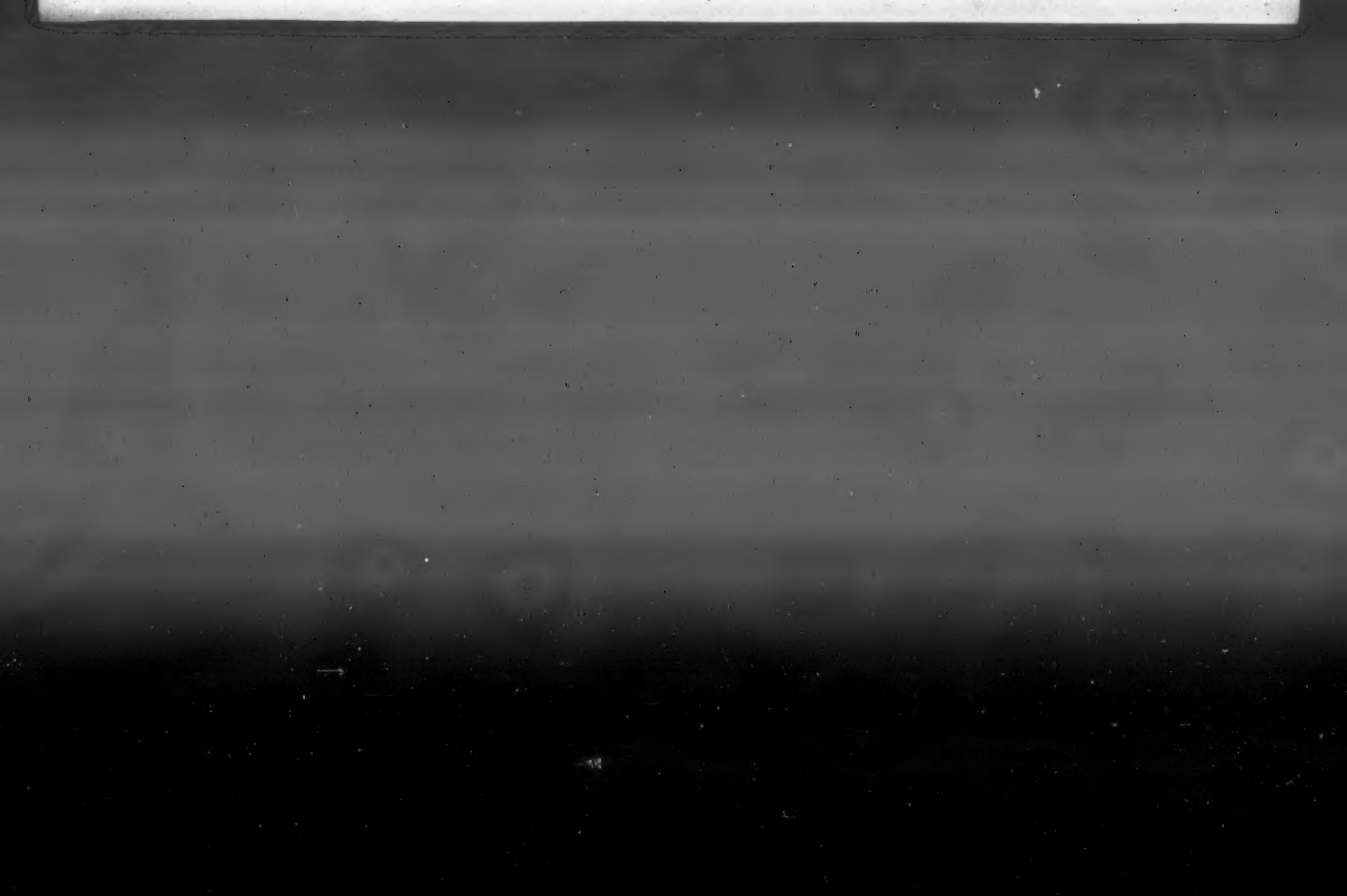

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